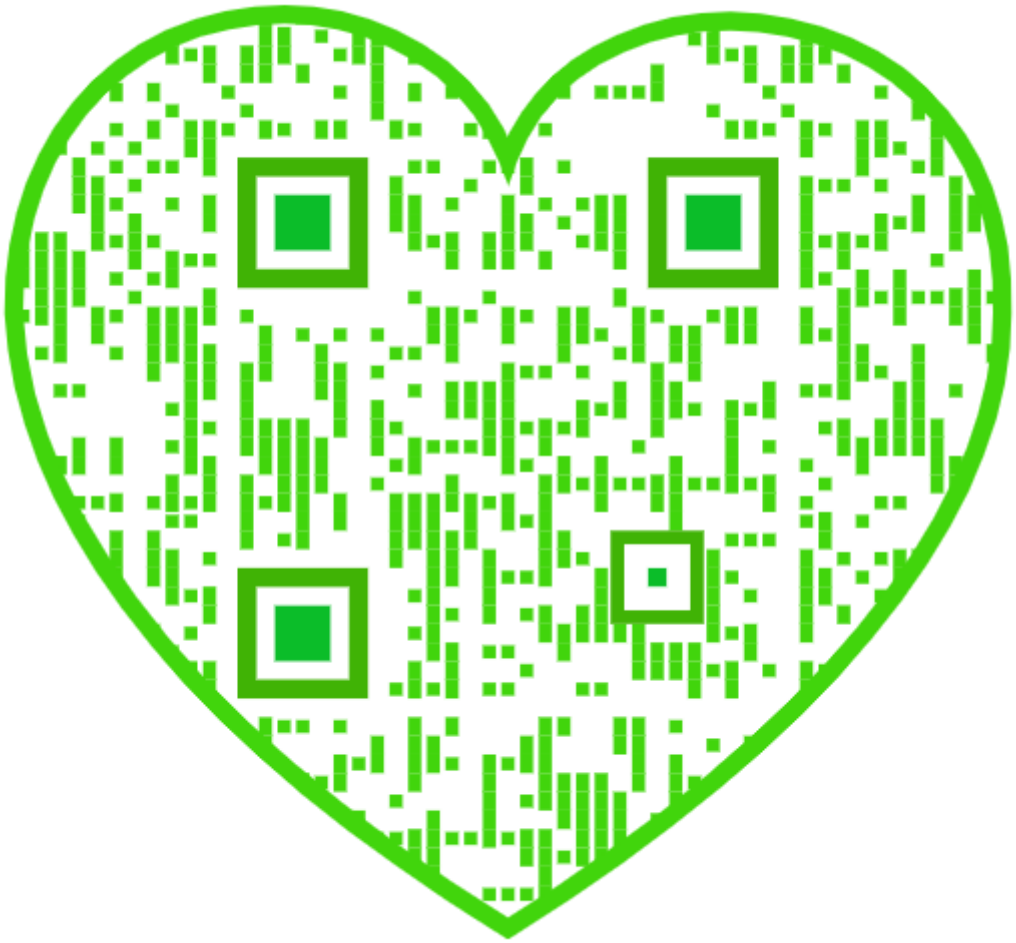

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A
Text Book of Chemistry

For the Use of Students

of the

Cincinnati Veterinary College

By

J. HENRY SCHROEDER, Ph. G., M. D.

Professor of Chemistry in the College

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By J. HENRY SCHROEDER, Ph. G., M. D.

PREFACE

The preface is chiefly required to state the limits of usefulness which have been outlined for this volume.

It shall serve as a text for the lectures in chemistry in the Cincinnati Veterinary College, and not take the place of the lectures. Moreover it is not a book of reference.

The aim in preparing the manuscript has been to adhere to the greatest simplicity in stating the subject; to develop in logical order the laws of chemistry and their application. It is required that the student shall know and *understand* the subject within the limits herein outlined.

That the book may fulfill its mission within its own limits, is the wish of

THE AUTHOR.

Cincinnati,
November, 1907.

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PART I.

THE THEORY OF CHEMISTRY.

Matter, Elements, Molecule, Atoms, Mass, Volume.

The study of chemistry is the study of the construction of matter, and of the laws governing the changes therein. *Matter* is anything that occupies space, and can be apprehended by the aid of our senses. The agency that brings about chemical changes is called *force*. A chemical change in matter destroys its identity, and a physical change merely its outward form.

Matter is divided into simple and compound matter. The former consists of one *element* only; the latter of a combination of elements. An element is the simplest substance known. Some seventy elements have been isolated, but only a limited number are of practical importance for our purpose. All material things are, therefore, made up of a combination of these elements, or of single elements.

The *quantity* of matter forming a substance is called its *mass*, expressed in units of *weight*. The

amount of space it occupies is called its *volume*. The relationship between a given weight of the mass and its volume is proportional to the *density* of the mass.

A Molecule is the finest and smallest particle of a mass of matter that can exist in a free state. It forms the limit of *physical* subdivision. By chemical means, however, a molecule may again be subdivided into two or more smaller particles, called *Atoms*. *An atom* is, therefore, the smallest particle of matter that can enter into chemical combination (to form the molecule).

It is a fundamental law in chemistry, that matter can not be created or destroyed.

Force, Cohesion, Mass, Chemical Affinity. States of Matter.

Force applied to matter is the direct cause of all physical and chemical changes. Without force matter would not change its state or position, it would be in a state of *inertia*. It is a force of gravitation, *cohesion*, that holds the molecules together to form the mass. Cohesion is, therefore, a molecular force; the difference between molecule and mass is one of form only. The atoms are chemically combined by a chemical force, called *chemical affinity*, inherent in atoms and elements, that causes atoms and elements to combine with each other.

The degree of compactness with which molecules are arranged within the mass, gives rise to three states of matter called *Solid*, *Liquid*, and *Gas*. The cohesion is greatest in the solid and least in the gas.

Specific Gravity.

Matter possesses weight and volume for a given mass. The comparative weight of different bodies of equal bulk is called their "specific gravity." It is not actual, but the ratio of relative, weight. Thus a given bulk of water weighs 1lb., the same bulk or volume of glycerine weighs 1¼lb. The glycerine is 1.25 times heavier than water: 1.25 is its specific gravity. Water is the accepted standard— its specific gravity is 1.

Weights and Measures of Mass.

The units of mass are expressed in various systems of weight. The old (American) system of weight consists of the pound unit, having 16 ounces of 437.5 grains each. In the same system the unit of volume is the pint, having 16 fluid ounces. The modern and simpler system, however, is the metric system of weights and measures. The unit is the *gram*, which is the weight of 1 cubic centimeter of water at 15°C. 1000 grams forms 1 kilogram, and 1000 cubic centimeters form 1 liter.

Heat, and its Action upon Matter. Latent Heat.

The force initiating all changes in matter is heat. The original source of heat is the sun. It sets in motion molecules and atoms, producing physical and chemical changes.

Molecular motion is produced by, and is accompanied by the production of, heat. Greater molecular vibration exhibits increased heat, and finally

it is accompanied by light (and electricity in certain bodies).

Aside from the original source, the sun, heat may be produced through friction and also through chemical changes (example, burning of a candle).

Changes produced by heat.

Heat acting upon matter produces increase in volume, by counteracting molecular attraction. Acted upon by heat, solid bodies *melt*, or *fuse*, at a temperature called the *melting point*, which is constant for the same substance. When a substance begins to melt, the temperature does not rise further, until the melting is complete, no matter how much more or greater heat is applied. This heat which during the process melting is absorbed, is stored up within the melting substance, and is called *latent* heat, because it is capable of doing work. It is given off in the same amount, if the melted substance solidifies again.

Heat applied to a liquid causes it to boil, at a temperature called the "*boiling point.*" It is constant for the same fluid under the same condition. Heat is rendered latent in the change from a fluid to the gaseous state. (The solidifying point of a liquid substance is likewise constant.)

Crystalline and Colloid Matter.

Substances passing from a liquid to the solid state may assume certain forms of definite outlines and angles, called *crystalline* forms. Substances incapable of assuming such forms are called *colloids*, or "wax like." "Rock Candy" is a good illustration of a crystalline formation.

Evaporation and Distillation.

Even at ordinary temperature water or many other fluids slowly vaporize, and more rapidly at a higher temperature. The process of vaporizing a liquid is called evaporation. It is proportional to the amount of heat applied and to the surface exposed to the air.

If the vapors are collected and cooled by abstracting the latent heat through a colder medium, the vapors enter, or change, into the liquid state. The process of vaporizing and condensing a liquid is called *distillation*, and the apparatus a *still*. Liquids having a low boiling point may be rapidly vaporized at a correspondingly low temperature. The more rapid the vaporization the greater the cold produced in the surrounding medium through the abstraction of heat. When readily soluble substances are dissolved in water, the temperature of the surrounding medium likewise falls, because of the heat absorbed by the dissolving substance. Upon this principle *freezing mixtures* are prepared. When, however, a chemical change is accompanying the process of solution, the temperature rises in the dissolving medium.

Measurements of Heat, Thermometers, Calories.

The amount of heat produced is measured by the thermometer, which registers the expansion of a column of mercury according to a fixed scale. Upon each thermometric scale, there are marked two fixed points, the freezing point and the boiling point of water. The *Centigrade* thermometer fixes the boiling point of water as 100°, and the freezing point as 0°. This temperature is designated upon the

Fahrenheit thermometer as follows: Freezing point 32°, boiling p. 212°; upon the *Reaumur* scale: Freezing point 0°, boiling point 80°. The *Celsius* scale is the same as the Centigrade scale.

The amount of heat that may be generated during the complete combustion (burning) of a substance of given weight, is called its *Caloric* value, the units *Calories.*

Chemical Effects of Heat and Electricity.

It has been stated that heat separates the molecules in the mass; it increases molecular motion. When the molecule is one of compound matter, it may be decomposed into its elements, if the degree of heat applied is sufficiently high. Or, if it is a molecule of simple matter it may be decomposed into its atoms, which, in turn, may produce other, and different, combinations at this temperature, according to the medium of matter which they meet. Heat may, therefore, induce chemical decomposition and produce chemical combinations. A low degree of heat merely favors any chemical change between different substances, by increasing the surface contact of the molecules.

Electricity.

It has long been known that the electric current can produce changes in chemical compounds. The current for such purposes may be generated in an *electric cell,* consisting, in its simplest form, of a beaker containing a fluid (usually sulphuric acid, or a solution of ammonium chloride) and two plates of different metals. The fluid acts more strongly upon one than upon the other, and there is consequently

generated electric force. The upper ends of the plate not immersed in the fluid, become charged with electricity, the zinc with *negative* and the other metal with *positive*, electricity. (Zinc and carbon are usually employed). This current may be conducted away from the ends ("poles") of the metals ("electrodes"), through wires, thus one wire carrying the negative, the other the positive electricity. If these two wires are passed into a solution of an inorganic chemical compound, the compound may be decomposed. (See further under Solution; Ions.)

Elements, Symbols, Valence.

It has been stated that all matter consists of one or more elements.

The more important elements are the following:

(*Metals*)		(*Nonmetals*)	
Potassium	(K)′	Oxygen	(O)″
Sodium	(Na)′	Chlorine	(Cl)′
Lithium	(Li)′	Bromine	(Br)′
Barium	(Ba)″	Iodine	(J)′
Strontium	(Sr)″	Nitrogen	(N)‴
Calcium	(Ca)″	Sulphur	(S)″
Magnesium	(Mg)″	Phosphorus	(P)‴
Aluminum	(Al)‴	Boron	(B)″
Manganese	(Mn)″	Carbon	(C)″
Zinc	(Zn)″	Silicon	(Si)″
Iron	(Fe)″	Hydrogen	(H)′
Lead	(Pb)″		
Bismuth	(Bi)‴		
Copper	(Cu)″		
Silver	(Ag)′		
Mercury	(Hg)″		
Gold	(Au)′		

Many of the elements do not exist in a free state in nature, because they possess an inherent tendency to combine with others; this affinity is called chemical affinity. The union of like atoms forms a molecule of "simple matter;" the union of unlike atoms a molecule of "compound matter." Elements possessing a very weak chemical affinity are called "inert."—*Symbols.* For convenience when writing, the names of elements are abbreviated in a definite manner, so that a letter stands for the name of the element, (thus H for Hydrogen). For purpose of dif-

erentiation another letter may be added. (B for Boron; Ba for Barium).

The Quantity of Combining Power, or Valence.

The chemical combination of elements and their atoms always takes place in definite proportions. The combination between Hydrogen and Oxygen, for instance, is always in the proportion of two parts of hydrogen to one of oxygen, (or two *atoms* of hydrogen to one *atom* of oxygen.)

The ratio in which an element combines with one atom of Hydrogen, is called its *Valence. Valance is, therefore, the quantity of combining (or replacing) power expressed in H units.*

For the purpose of demonstrating the combining power of elements, we assume that the atoms have bonds, or links, with which they link to the bonds or links of another element. Thus H has one bond, H——, O$^{=}$ two bonds. It is a law that when two atoms combine with each other, there must be produced an equal number of bonds for each of the combining elements. If the valence of one element is less than of the other, more atoms must be taken. To form the compound of H + O, water, it can only be accomplished by taking two H atoms, thus: H——
H—— $^{=}$O. When all the bonds are satisfied the compound is "saturated." By referring to the preceding list of elements, the bonds have been indicated thus, O″.

Hydrogen is the unit for valence. If the combining power of another element can not be studied from direct combination with hydrogen, its compound with some element may be studied the valence of which has been determined. Thus H

does not combine directly with Na; but Na combines with Cl to form NaCl. Cl has one bond, therefore Na must also have only one bond. Elements having the valence *one* are called *Monads* (univalent); those with valence II. Dyads (bivalent); with the valence III., Triads (trivalent); with the valence IV.,Tetrads (quadrivalent), etc.

Variation of Valence.

Under some conditions the valence of an element may vary. Thus an element having the valence I. may exhibit a valence of III., V., and VII. An element having the valence II. may exhibit the valence IV., VI. and VIII. The variation is with two bonds increase or decrease. This variation is explained in this way: We credit the element with the highest number of bonds it ever exhibits, thus Chlorine, Cl^{VII}. If two adjacent bonds were, temporarely to satisfy each other, there would finally be left only one valence Cl^{I}; under certain conditions two or more adjacent bonds might be again opened, increasing the valence by two each time.

Chemical Compounds.

The chemical combination of two or more different atoms forms a chemical compound. A chemical compound must be differentiated from a "Mechanical Mixture" of two or more elements. In a mixture, the mixed elements may again be separated, unaltered, by physical means. But under suitable conditions their atoms may combine. Favorable conditions are such as allow an intimate contact with the molecules of the combining substances

This may be accomplished by dissolving the substances in water, or by applying heat.

Free elements exist in the form of molecules, that is, their atoms are linked to atoms of the same kind. While the selection between atoms is always most strongly exhibited between those of different kinds, when a simple molecule has once formed, this affinity is not so strongly exhibited, (as in H— —H, H_2). By the application of heat this union may be broken up, and then the bonds, temporarely free, will attract the bonds of different atoms that may be present likewise broken up, and a compound molecule will form, thus H— —H + Cl— —Cl + heat = H— H— + Cl— + Cl— = H— —Cl + H— —Cl. Single atoms of elements with free bonds, exist for that brief moment when they are separated from compounds, and this state is called the *nascent* state. Their chemical affinity is most marked in the nascent state.

Compound Radicals.

In a *normal* or *saturated* compound all bonds are saturated; it cannot combine with anything else, thus H——
H——O If now one or more of the composing elements were removed, there would be left a free bond, thus H—— =O, or ——O—H, or —OH. This *rest* of the compound is unsaturated; it can combine with other elements and is called a *compound radical.*

A *compound radical is, therefore, an unsaturated rest of a chemical compound.*

Radicals, as a class, terminate in *yl*, and are called according to the elements contained therein, or according to the compound of which they were part. Thus —OH is *hydroxyl.*

Atomic and *Molecular Weights.*

If HCl, hydrochloric acid, is analyzed, it will always be found to consist of one part of H and 35.37 parts by weight, of Cl. In other words one atom of H and one atom of Cl have combined to form 1 molecule of HCl. The ratio of combination is hydrogen 1 and chlorine 35.37. These relative weights of the atoms, in the ratio of which the combine, are called their respective *atomic weights.* The total weight of the combined atoms (in the molecule) is the *molecular weight.*

Classification of Elements.

By referring to the list of elements it will be seen that they have been grouped as *Nonmetals* and *Metals.* Metals are usually solid at ordinary temperature. They are hard, and acquire a metallic lustre. The nonmetals may be solids, liquids, or gases at ordinary temperature. They do not possess the physical properties of metals. The nonmetals are *acid-forming,* and the metals *basic,* or base-forming elements.

Classification of Chemical Compounds.

Chemical compounds composed of two elements only are called "binary" compounds; those composed of three elements are called *ternary* compounds. The binary compounds are designated by naming the elements according to their order in the compound, terminating the last word with *ide,* thus KBr, Potassium brom*ide.*

Acids, Bases and Salts.

Chemical compounds may also specially be subdivided into 3 classes: Acids, Bases and Salts.

Acids. An acid is the chemical combination of H with and acid forming element. The acid forming elements are among the nonmetals. There are two groups of acids: binary and ternary acids. A *binary* acid is the direct union of H and the acid forming element. A *ternary* acid contains three elements: H, the acid forming element, and oxygen. They are, therefore, sometimes called *oxy*acids. Ternary acids are not formed directly, but indirectly by first forming from the acid forming element the *acid forming oxide.* This acid forming oxide, with water, forms the acid. For example:

The acid forming element S forms SO_2.

$SO_2 + H_2O = H_2SO_3$.

The acid forming oxides are sometimes called *acid anlydrides*, that is acids minus the water molecule.

Different ternary acids from the same element.

The intermediate product of ternary acids, the acid forming oxide, is in chemical character and composition depending upon the valence of the acid forming element. The four oxides of S will therefore be as follows: (The acids are also formed.)

$S'' + O'' = SO + H_2O = H_2SO_2$ *Hypo*sulphur*ous.*

$S^{IV} + 2O'' = SO_2 + H_2O = H_2SO_3$ Sulphur*ous.*

$S^{VI} + 3O'' = SO_3 + H_2O = H_2SO_4$ Sulphur*ic.*

$S^{VIII} + 4O'' = SO_4 + H_2O = H_2SO_5$ *Per*sulphur*ic.*

Nomenclature of Acids.

Binary acids, example HCl, as a class have the prefix *hydro*, and the termination *ic*, thus hydrochloric; H_2S, hdrosulphuric, acid.

Ternary acids are named according to valence of the acid forming element. Granting that an acid forming element exhibited only two valences, we would then call the lower valence acid, if the acid forming element were S, sulphur*ous* acid, and the higher, sulphur*ic* acid. Where there are four different valences exhibited, however, we designate the lowest valence acid by the prefix *hypo*, and the highest valence acid by the prefix *per*, thus the ternary acids of S; *hpyo*sulphur*ous,* sulphur*ous,* sulphur*ic* and *per*sulphur*ic*, acid, (*hypo*, meaning "below" (ous) and *per* meaning "above" (ic). The acid forming oxides are designated in the corresponding manner.

Properties of Acids.

Physical: Acids are gaseous, (dissolved in water) or liquids. They have a sour ("acid") taste, and are more or less caustic, destroying organic tissue.

Chemical: Acids turn blue litmus paper red ("acid *reaction*"). The hydrogen may be replaced by a metal.

Acid radicals. An acid may be said to possess two halves. The replaceable H, and the balance. This balance would be, without the H, the acid radical, thus —Cl, the acid radical of hydrochloric acid (HCl); = SO_4 the acid radical of sulphuric acid (H_2SO_4).

Chemical Salts.

A chemical salt is the union of a metal, (or *basic* radical) with an acid radical. In its simplest form it is produced when the H in an acid is replaced by a metal, thus:

H Cl + Na = *Na Cl* + H.

The H need not necessarily be replaced by the metal in its free metallic state, but the metal may be obtained from its combinations, as will be shown. (See *Bases*, and *Ions*.)

Denomination of *Salts*.

A salt is designated according to the metal and the acid radical. Binary acids form salts designated, like binary compounds in general, by the termination *ide*: Na Cl is sodium chlor*ide*.

Salts of ternary acids are designated according to the acid radical. Thus of the acids of sulphur and sodium: *Hypo*sulphur*ous* acid forms sodium *hypo*-sulph*ite*. Sulphur*ous* acid forms sodium sulph*ite*. Sulphur*ic* acid forms sodium sulph*ate*. *Per*sulphur*ic* acid forms sodium *per*sulph*ate*.

Acid, Neutral, and *Basic Salts*.

When all the H in an acid has been replaced by the metal, we obtain a *neutral* salt; (Na_2SO_4) when only part of the acid has been replaced we obtain an *acid* salt ($NaHSO_4$), having still acid properties. Instead of speaking of them as *acid* salts (sodium acid sulphate), they are usually designated as follows: Sodium *bi*sulphate, sodium *bi*carbonate, etc.

Bases are the hydrates of the metals, thus Na OH. The OH group or radical is derived from H—O—H, water. Some bases may be formed by decomposing the water directly as of sodium: Na + H—O—H = *Na OH* + H. Other elements form the hydrates by dissolving the *basic oxide* in water, thus Ca O + H—O—H = (Ca $(OH)_2$).

Formation of Salts from Acids and Bases.

Bases may be divided into two halves of the molecule, the metal (basic radical) and the OH group, thus Na OH = Na—OH.

When an acid acts upon a base, the H of the acid may be replaced by the metal of the base (see acids, thus: Na OH + HCl = *Na Cl* + H OH, the nascent H of the acid, and the nascent OH group forming water. Thus an acid and a base form the corresponding salt. —

The *basisity* of an acid is its base neutralizing power indicated by the number of the replaceable H in the acid. HCl. is monobasic. H_2SO_4 dibasic.

The *acidity* of the base is the acid neutralizing power of the base thus Na OH is mono acid, Ca $(OH)_2$ is diacid.

(A *basic* salt is a salt, not neutral, still possessing basic properties.)

Solution. Ionization.

A solution is the homogeneous mixture of a solid or gas with a fluid. The substance undergoes solution in the *solvent*; the commonest solvent is water. The molecules of the dissolving substances pass between the molecules of the solvent. If a solvent will dissolve no more of the substance it is called a *saturated* solution, a saturated solution may still be a solvent for another substance.

Aside from the fine molecular division of the dissolved substance, there is another change. The molecule is separated into its *ions, but not chemically*

decomposed into its atoms. The ions are still part of a chemical combination. In binary compounds, (acids and salts), the ions correspond to individual elements and atoms, thus Na Cl separate into sodium ions and chlorine ions. The ternary compounds do not separate into the individual elements but into parts corresponding to the radicals; thus H_2SO_4 into H_2 ions and SO_4 ions, or Na_2SO_4 into Na_2 ions and SO_4 ions. The process of separation is called "Dissociation" of the molecule, or "ionization." Dissociation is most complete in dilute solutions, and in certain solvents, of which water is the best.

Electric Decomposition of Compounds.

When an electric current is passed into a solution containing a compound dissociated into ions, the ions are attracted to the poles of the electrodes, some to the positive, and some to the negative pole. That is because the ions are electrically charged bodies. Unlike kinds of electricity attract each other; therefore the ions attracted to the positive pole must be electro negative, and those attracted to the negative pole, electro positive. Thus of Na Cl, Na positive (+) and the Cl negative (—); of Cl_2O, Cl +, O—. Thus the compounds between any two elements have been studied; it has been found that an element may be positive in one compound, and negative in a different compound (see Cl above). When the names of elements are arranged in a serial form according to their electro chemic character toward each other, we have the socalled *electro-chemic series.* It is of practical help by indicating which element in a compound should be written first, thus Na Cl, and not Cl Na; the positive element precedes. Furthermore, an element may only change its valence when

it is electro-positive in a compound. Lastly, an electro-positive or electro-negative element may be replaced by one more electro-positive, or electro-negative, than the element in question.

The electro-chemic series is as follows:

Oxygen, Sulphur, Nitrogen, Chlorine, Bromine, Iodine, Phosphorous, Arsenic, Chromium, Boron, Carbon, Antimony, Silicon, Hydrogen, Mercury, Silver, Copper, Bismuth, Lead, Iron, Zinc, Manganese, Aluminum, Magnesium, Calcium, Strontium, Barium, Lithium, Sodium, Potassium.

Interchange of Ions, Double Decomposition.

Law: Whenever there are present in the same solution ions necessary to form an insoluble compound, that compound will form. Being insoluble, it separates from the solution as a precipitate.

In order to know what ions will form insoluble compounds, one must know the insoluble compound. Thus it can easily be ascertained that HgI_2 is insoluble. Therefore, if Hg ions and I ions meet in solution, the compound HgI_2 will form, thus $2KI + HgCl_2 = HgI_2 + 2KCl$. This interchange of ions is also called double decomposition.

When acid and basic ions meet, there is likewise an interchange, a salt being formed:

$$Na\,OH + HCl = Na\,Cl + H—O—H.$$

Deliquescence, Efflorescence.

Some substances (solids) are so soluble in water that they attract water from the air when exposed,

and liquify in it; they are said to be *deliquescent.* When water is physically associated with a compound, as *water of crystallization*, (that is the water needed to form a crystal, or included in the crystal), it may lose this water of crystallization when exposed to the air; it is said to be *efflorescent.*

Dialysis and Osmosis. Diffusion.

All crystalline substances, when in solution, will pass out of this solution into water, when the water is separated from the surface of the solution by an animal membrane. Colloid substances do not pass out in this manner. The process is called *dialysis.*

Osmosis is the passing of a current of water toward a concentrated solution of some salt, from which the water is separated by a membrane.

Diffusion is the passing of one liquid into another of different specific gravity when the two liquids form lawers one over the other.

Chemical Formulae, Reactions, Reagents and Equations.

A chemical formula is a collection of symbols stating the composition of a compound. Thus NaCl is the chemical formula for sodium chloride; H_2SO_4 for sulphuric acid.

A chemical reaction is the action of one substance with another, involving chemical changes.

The substances taking part in a chemical reaction are called *reagents.* The written demonstration of

the changes, qualitative and quantitative, involved in a chemical reaction is an *equation.*

Thus, the following equation demonstrates the chemical reaction between the reagents sodium hydrate and sulphuric acid.

$$2NaOH + H_2SO_4 = Na_2SO_4 + 2H_2O.$$

An equation expresses what actually takes place. It is not an equation if the quantities or reagents involved are not equal the sum of the products. When using a single element as a reagent the least that may be taken of it is a molecule. Thus it is proper to write $2H_2 + O_2 = 2H_2O$, and not $2H + O = H_2O$.

H stands for *one atom* of H. 2H stands for 2 atoms of H (H—, H—,). H_2 stands for *one molecule* (H— —H).

Quantitative expression: A large figure *preceding* a symbol multiplies every part of the formula: thus $2H_2SO_4$ multiplies as follows: 4H, 2S, 8—O atoms in the two molecules. A small figure *following* a symbol, multiplies the preceding symbol only; when a formula is in parenthesis, a small figure following the parenthesis multiplies every element in the parenthises the same as when a large figure preceds the first element in the compound with or without parentheses.

PART II.

INORGANIC CHEMISTRY.

Chemistry is divided into "Inorganic" and "Organic" Chemistry. Organic chemistry considers compounds of *carbon* with H, O, N, S, and P. These organic compounds are called "carbon compounds." The compounds of all other elements belong to inorganic chemistry; this is the first division of study.

The study of the inorganic compounds necessitates a study of the elements that form these compounds. Occasionally these elements are in their *free* state of medical importance.

For purpose of study elements may be grouped, according to certain points of resemblance in their character. It is convenient to arrange them as follows:

I. The Nonmetals.

H, O, Cl, Br, I, N, S. P, Si, C.

II. The Metals.

subdivided into:

a) *The Alkaline Metals:*

K, Na, Li, (NH_3 group);

b) *The Alkaline Earths:* Ca, Sr, Ba;

c) *The Earths:* Type: Aluminum, Al;

d) The remaining metals, ungrouped:

Mg, Ag, Au, Cu, Hg, Al, Pb, As, Sb, Bi, Cr, Mn, Fe.

The Elements.

Some elements occur in the free state in nature. Others only as chemical compounds. For purpose of demonstration elements chemically combined may be liberated. Chemical compounds may then again be formed from such elements. All chemical changes that occur must be carefully observed, *and every step must be thoroughly understood.* It contributes more than anything else to the habit of accurate observation and thinking.

The Nonmetals.

Hydrogen, Hydrogenium, Symbol H, Val. I, At. W. 1.

Hydrogen does not occur free in nature to any extent; mostly combined with water, forming 1-9 its weight. It is a colorless, odorless gas, lighter than air, insoluble in water. It is *combustible* ("burns") in air. It does not "support" combustion of other elements. H is a constituent of all acids. It is of no direct medicinal use.

Chlorine, Cl, Val. I—VII, Atomic W. 35.37
Bromine, Br, Val. I—VII, Atomic W. 79.76
Iodine, I, Val I—VII, Atomic W. 126.53

These three elements have been grouped together for convenience of study, because they have similar properties. There is a gradual increase in density, *Chlorine* is a gas; *Bromine* a liquid; *Iodine* a solid. Bromine and Iodine, are, however, easily volatilized. Note also the systematic increase in atomic weight.

Their chemical properties also resemble each other closely. With Hydrogen they form binary acids. They also form corresponding oxyacids. The salts of these acids have a close physical resemblance. Chlorine, Bromine and Iodine occur in nature combined as Chlorides, Bromides, Iodides and Iodates.

The following points are of particular interest:

Chlorine. The most common preparation (salt) is Sodium Chloride, NaCl, or common table salt. It is a constant constituent of the animal tissue. Certain preparations are official, because they yield *free* chlorine: Chlorine water, chlorinated soda (containing chiefly sodium hypochlorite), chlorinated lime, (bleaching powder), containing calcium hypochlorite. Most chlorides are water soluble. *Insoluble chlorides*, $PbCl_2$, HgCl, Hg_2Cl_2. Chlorides do not act with their chlorine contents as free chlorine. The official binary acid is *Hydrochloric Acid*, containing about 32 per cent. HCl (dissolved in water). The commercial product, impure, is called muriatic acid. The "diluted hydochloric acid" is of 10 per cent. strength.

The Chlorates are the salts of chloric acid, of interest is chiefly $KClO_3$.

When heated it parts with its oxygen. It may likewise be decomposed when mixed with organic substances (Glycerine, Sugar, and also Sulphur), and when friction is applied to such mixtures. Dangerous explosions have thus occurred.

Bromine. Preparations of medicinal interest, the bromides, chiefly KBr, NaBr, NH_4Br, $SrBr_2$. These bromides are soluble. (*Insoluble Bromide*, AgBr).

Iodine. Insoluble in water. Soluble in alcohol and chloroform, and in solution of KI.

Preparations of Iodine. *a* Containing free iodine, Tincture of Iodine; Compound Solution of Iodine, (Lugols Solution); Ointment of Iodine. *b* Certain organic preparations acting with liberated (available) Iodine: Iodoform, Thymol Iodide. Of the iodides there are official KI, NaI, HgI_2 as the salts of chief interest.

(*Insoluble Iodides*, PbI_2, HgI_2, AgI).

Note: I, Cl, Br, are called *Halogens*; their binary acids, *Haloid* acids.—

Oxygen, Symbol O, Val. II, Atomic W. 15.88.

Oxygen exists in the atmosphere mixed with Nitrogen, to form 1-5 of the volume of air. It also forms, combined, 8-9 of the weight of water.

Oxygen is a gas, odorless, tasteless, and slightly soluble in water. It combines more or less readily with most other elements, directly or indirectly, forming the *oxides*. Many substances burn in oxygen, that is, oxygen "supports combustion." Oxygen supports also life, which is a process of continuous combustion within the tissues.

Ozone is a special form of oxygen having 3 atoms to the molecule, O_3. It represents an especially active form of oxygen.

Water, H_2O. The purest water is dilled water. Rain water, collected uncontaminated is also reatively pure. *Spring water* is usually contaminated with salts abstracted from the soil. When the impurities consist of carbonates (of Ca, Mg), which may be precipitated by boiling, we have a "temporarely" *hard* water; if the sulphates of these metals are

present, it is *permanently* hard, because the impurities can not be so separated. *Mineral* waters are spring waters that contain relatively large amounts of salts in solution. They may, therefore, be of medicinal interest.

Water is a solvent for many substances. It forms a necessary part of the food supply of living beings.

Hydrogen dioxide, H_2O_2 is the chemical union of two hydroxyl groups OH— —OH.

It is an ingredient in the official *water of Hydrogen dioxide.* The compound is easily decomposed, sometimes with explosive violence, yielding free oxygen ($H_2O_2 = H_2O + O$).

Note. The process of uniting with oxygen is called "oxydation;" substances that yield free oxygen are called "oxydizing agents." Substances that take away oxygen from compounds are called "reducing agents."

Sulphur, S, Valence II—VIII, Atomic W. 31.83

Sulphur occurs in a free state, and may be kept unchanged. It is a solid, of yellow color, insoluble in ordinary solvents; soluble in oils, and CS_2. When exposed to air, it forms traces of SO_2 and H_2SO_4. It is sometimes used in medicine in its free state.

Compounds of importance: H_2S, hydrosulphuric acid. Many metallic salts, suphides, are insoluble, and its is, therefore, a useful reagent in chemical analyses.—

SO_2, produced when sulphur burns in air, is a strong disinfecting and bleaching agent.

H_2SO_4, sulphuric acid, is one of the strongest acids we have. It liberates most other acids radicals from their compounds. It is 1.8 times heavier than water; because of its heavy, oily appearance it is called "Oil of Vitrol." Its salts are the sulphates. Of importance are K_2SO_4, Na_2SO_4, Zn SO_4 (White Vitrol), $FeSO_4$ (Green Vitrol), Cu So_4 (Blue Vitrol).

(*Insoluble sulphates*, $CaSo_4$, $PbSO_4$, $BaSO_4$).

Nitrogen, N, Valence III—V, Atomic W. 13.93.

Nitrogen forms 4-5 of the air. It shows little chemical affinity for other elements (it is "inert"). As an element it is of no medicinal importance.

Chemical compounds. The union of N and H forms *Ammonia*, NH_3. As a compound it resembles in many respects the bases (Metals), and is, therefor, frequently classed with them. With water it forms $NH_3 + H_2O = NH_4 OH$ (Ammonium hydrate). The radical Ammonium, NH_4,—combined with acid radicals, yields corresponding salts (NH_4 Cl). Ammonium is a volatile base, and the salts are more or less volatile. Important Ammonium Salts are $(NH_4)_2CO_3$. NH_4Cl.—The volatile ammonium base may be liberated by a stronger, fixed, base: $NH_4Cl + KOH = NH_4OH + KCl$.

NH_4OH, dissolved in water, yields Ammonia water, (10 per cent. strength). A 28 per cent. solution is called the Stronger Water of Ammonia. An alcoholic solution of NH_3 is called Spirit of Ammonia.

Nitrohydrochloric Acid, is prepared by mixing HNO_3 and HCl. It contains free Cl and Nitrosyl

chloride. It is called "Aqua Regia," because it is the only acid dissolving gold, due to the free (nascent) chlorine.—All neutral (normal) nitrates are saluable in water.

Phosphorous, Symbol P, Val. III—V, Atomic W 30.96

Phosphorous is a solid, wax like substance. It does not occur free in nature, but is obtained from the phosphates (of bones). It must be kept under water, because, in its free state, it inflames when coming in contact with air. Phosphorous is insoluble in water, it is soluble in carbon bisulphide, chloroform, absolute alcohol, and in fatty oils. The oxides of Phosphorous P_2O_3 and P_2O_5 form Phosphorous and Phosphoric acid, respectively. The formation of the oxyacids from Phosphorous is irregular, and can not be discussed here. There exists also a Hypophosphorous acid. Of interest are chiefly the medicinal preparations and salts called the Hypophosphites (of Na and Ca), and the phosphates (of Na and Ca).

Boron, B, Val. III, Atomic W. 10.9.

Boron is found in nature combined in *Borax* and *Boric acid.* The acid itself is of medicinal interest. It has mild antiseptic properties. The salt, *Sodium borate*, or borax, is largely used in medicine for antiseptic purposes.

Carbon, C, Val. II—IV, Atomic W. 11.97.

Carbon is a widely distributed element. It is best known as Charcoal. There are other forms of Car-

bon, more or less pure, such as *Coal*, *Graphite*, and the *Diamond*. The latter is the purest crystalline, form of Carbon.—Carbon, in the form of Charcoal, absorbs gases readily when dry. Burned in the air, Carbon forms CO_2. The acid, H_2CO_3, is Carbonic acid. It is volatile and possesses weak acid properties.—Carbon is a constitutent of all organic matter. Charcoal is obtained from animal tissue (*animal charcoal,*) and from any wood, (*Willow* charcoal) when either is burned with insufficient access of air, Organic substances "char." Carbon is the basis of the Carbon compounds (Organic chemistry).

The Gas Flame and the Bunsen Burner

Illuminating gas is a mixture of various gases rich in Carbon. When the gas is lighted as issuing from the jet, the separate constitutents of the gas, C and H, undergo combustion in the air, forming CO_2 and H_2O. Not all of the Carbon undergoes combustion, but the surrounding heat renders these carbon particles *incandescent*. If air is mixed with the gas before it is ignited, enough oxygen is supplied the gas, that all the carbon is consumed, and more heat, but no light, is produced, therefore a blue flame (*Bunsen Burner*).

The Metals.

The Alkali Metals.
The Alkaline Earths.
The Earthy Metals.
The Heavy Metals.

The Alkali Metals.

Potassium, (Kalium) K, Val. I, Atomic W. 39.1.
Sodium, (Natrium) Na, Val. I, Atomic W. 23.
Lithium, Li, Val. I, Atomic W. 7.01.

The alkali metals are so called because of the strongly alkaline character of their hydrates. These metals have several properties in common; they do not exist in their free state in nature; they are soft and wax-like in consistency. They decompose water readily, forming free H and the hydrate of the metal ($K + H—O—H = KOH + H$). Their oxides are not stable, but tend to form hydrates energetically when coming in contact with moisture. The salts of the alkaline metals are practically all soluble in water, including their carbonate and phosphates (except those of Li).—There is a close physical resemblance, and similarity of properties and actions, between the corresponding salts of these metals.—As a rule, the hydrates, carbonates and phosphates of these metals will precipitate out of solution the salts of the other metals, when they are mixed with solutions of their soluble salts. (Incompatibility, example, $ZnSO_4 + Na_2CO_3 = ZnCO_3 + Na_2SO_4$).—

Potassium. Important preparations and salts. *KOH, (Potassium hydrate,* Potassa, in Solution of

Potassa. K_2CO_3, (*Potassium corbonate,* Sal Tartar). $KHCO_3$ Potassium bicarbonate, $KClO_3$, Potassium chlorate. KBr, Pot. Bromide. K_2SO_4. Potassium sulphate. KNO_3, Potassium nitrate (Salt petre). $KMnO_4$, Potassium permanganate. KI, Potassium iodide.

Sodium, preparations and salts of importance: NaOH, Sodium hydrate, Soda. Na_2CO_3, Sodium carbonate, (Washing Soda). $NaHCO_3$ Sodium bicarbonate, (Baking Soda). NaCl, Sodium chloride, (Table Salt). NaI, NaBr. Na_2SO_4, Sodium sulphate, (Glauber's Salt). $NaNO_3$.

Note: Whenever the solution of a bicarbonate is boiled, it is changed into a carbonate by giving off H_2CO_3, thus, $2NaHCO_3 + \text{heat} = Na_2CO_3 + H_2CO_3$.

The Alkaline Earth Metals.

Calcium, Ca, Val. II, Atomic W. 39.91.
Strontium, Sr, Val. II. Atomic W. 87.3.
(*Magnesium*, Mg, Val. II, Atomic W. 24.3.)
Barium, Ba, Val, II, Atomic W. 136.9.

The members of this group are so called, because they resemble the alkaline metals on the one hand, and the earthy metals on the other.

They resemble the alkaline metals, in that the metals can not be kept, unprotected, in a free state. They do not occur in nature in a free state. The metals will decompose water, but not so readily as the alkali metals. Their oxides form hydrates, with water, with more or less readiness; they have, therefore, an "alkaline" character. In general, it may

be said, that they are less energetic than the alkali metals.

They resemble the earthy metals, in that their oxides have greater stability than the oxides of the alkaline metals—they do not form the hydrates as readily when coming in contact with water. Their carbonates and phosphates are insoluble in water.—The metals of the alkaline earth group show, therefor, a gradual tendency to transition, in their chemical properties, toward the group of earthy metals.

Calcium, important preparations and Salts:

CaO, Lime, when coming in contact with water, *slakes,* i. e. it forms $Ca(OH)_2$, thus $CaO+H—O—H=Ca(OH)_2$. $Ca(OH)_2$ is sparingly soluble in water, forming "Lime water." $CaCl_2$ (Calcium chloride) and *Chlorinated lime* are chemically two distinct compounds. Chlorinated Lime is lime charged with chlorine, forming, among other compounds, calcium hypochlorite, which, upon exposure to air, or more readily upon the addition of acids, liberates *(available)* chlorine.

$CaSO_4 + 5\%$ of water. "Dried Calcium Sulphate." Calcium sulphate, commonly called *Plaster of Paris.* It is native Gypsum, dried to 5% of water. If it contains more, or less, water it will not "set," that is, harden, when it is again mixed with water.

(Calcium Carbonate and Calcium Phosphate are insoluble in water.)

Calcium phosphate forms the Chief mineral (solid) constituent of bone. Deficiency in this salt in bone leads to a softening of bone.

Strontium and *Barium*, and their salts do not possess great medicinal interest. The Strontium bromide is sometimes used to replace KBr, and NaBr.

$Ba(OH)_2$ in solution forms the Baryta water. $BaSO_4$ is of chemical interest, because it forms a very insoluble sulphate, and is therefore used to test for H_2SO_4 or its salts.

Magnesium is not usually classed with the alkaline earths, but it is considered here as a matter of convenience. It may be said to incline still more, than the other members of this group, toward the earthy metals. When ignited Mg burns in air to form MgO, the particles being rendered incandescent, producing a most brilliant (flash) light.

MgO, Magnesia, is usually called *Calcined* Magnesia, because it may be prepared by igniting the carbonate, thus $MgCO_3+heat=MgO+CO_2$. (*Note:* "Calcination" is the process of igniting a carbonate, and producing an oxide.) There is also a heavier, denser, form called "Heavy Magnesia." It does not form the hydrate readily when coming in contact with water; it is insoluble. (*Note*, insoluble oxides, in contact with water, *act* as hydrates, $Mg(OH)_2$, and any other hydrate that cannot be formed directly by dissolving the oxide in water, may be formed indirectly by precipitating a soluble salt with another hydrate, thus $MgSO_4+2NaOH=Mg(OH)_2+Na_2SO_4$.)

$MgSO_4$, Magnesium sulphate, is commonly called Epsom Salt, because it is found in the Springs at Epsom.

The Earths.

Aluminum, Al, 27.04 Atomic W. Val. III.

Aluminum is the commonest and typical representative of the group of earths. The other members are of only scientific or technical interest ("the rare metals.")

Aluminum is found in nature as an earth or clay, (hence the name "earthy metals"), as an oxide or hydrate. The metal itself is well known. It is exceedingly light, and does not rust upon exposure to air.

Aluminum hydrate, $Al_2(OH)_6$ forms when a soluble Aluminum Salt is precipitated by Sodium Carbonate. It must be distinguished from *Alum* (Alumen), and from Aluminum Sulphate.

Alumens, as a class, are double salts (two different bases) one of which is Al. Thus we have a Potassium Alum, Ammonium Alum, and Iron Alum, according as to whether Potassium, Ammonium, or Iron is associated as a base with the Aluminum. The official Alum is the Potassium Alum.

Aluminum and Potassium Sulphate.

There is not infrequently substituted the Ammonium Alum. The latter may be detected by adding to a solution of the Alum, a solution of KOH, when the Ammonium, if present, is liberated. All alums contain a large percentage of water of crystallization (24 Molecules). When Alum is dried, it increases in strength accordingly, and is then called "burnt" or dried Alum.

The Heavy Metals.

The remaining metals are so called, because of their relatively heavy specific gravity (All over 6.) Most of them are well known in their free state, and when kept dry, do not easily rust or tarnish. Metals like Gold, Silver, and Platinum do not rust at all, and are, therefore, called "noble metals." These metals do not desompose water except at very high temperatures. Their oxides are not soluble in water and do not form hydrates, but in the presence of water act as hydrates. Their carbonates (and some other salts) are insoluble in water. The members of the group of heavy metals have marked metallic properties.

The heavy metals are found in nature either as free metals, sometimes associated with other metals, or as sulphides or oxides, and may be separated from these compounds by proper chemical methods. (They are said to occur as *ores,* and are found in mines.)

Zinc. Zn, Atomic W. 65. 10. Val II.

Preparations and Salts: ZnO, Zinc Oxide. $ZnCO_3$, Zinc Carbonate. $ZnSO_4$, Zinc Sulphate (White Vitriol). $ZnCl_2$, Zinc Chloride.

Silver (Argentum) Ag, Atomic W. 107.66. Val I.

Preparations and Salts: $AgNO_3$, Silver Nitrate. Solutions of Silver Nitrate must only be prepared

with distilled water. Any organic matter reduces a solution of Silver Nitrate to Silver Oxide and Metallic Silver. The water must be free from Chlorides (insoluble AgCl.) The solution must be preserved protected from light.—*Diluted* Silver Nitrate is the salt mixed with Potassium Nitrate. *Fused* Silver Nitrate is prepared in stick form, to be used for cauterizing purposes. It contains a trace of AgCl to toughen the mass. (No solutions of organic substances should be mixed with solution of Silver Nitrate.)

(*Insoluble salts,* AgCl, AgBr, AgI.)

Copper, Cu. Atomic W. 63.18. Val. II.

Preparations and Salts: $CuSO_4$, Copper Sulphate. (Blue Vitriol, Blue Stone.)

(Fehling's solution consists of $CuSO_4$ and Potassium Hydrate and Potassium and Sodium Tartrate, dissolved in water).

Mercury, Hydrargyrum. Val. II. Atomic W. 199.6.

Mercury is the only liquid metal we possess. At a very low temperature it solidifies, however. Metallic Mercury is sometimes used in a free state.

Preparations and Salts: Some preparations contain free Mercury: Mercury with Chalk, and the Mass of Mercury, for internal administration—The Ointment of Mercury for external application.— Hg_2Cl_2 Calomel, Mild Mercurous chloride (Subchloride of Mercury).

$HgCl_2$, Corrosive Mecuric chloride, Corrosive Sublimate, Bichloride of Mercury. *Poison!*

Calomel must be carefully distinguished from the Corrosive Sublimate. The english official names have been fixed for the purpose of avoiding errors. Calomel is an insoluble powder. Corrosive Sublimate a crysalline solid, soluble in water. Calomel is comparatively nontoxic; Corrosive Sublimate very toxic.

Calomel must not be exposed to strong sunlight, nor mixed with chlorides, that conversion to Mercuric Chloride may not occur. Corrosive Sublimate may be detected as an impurity in Calomel, by dissolving, or mixing the powder with water, filtering, and testing the filtrate with KI: $HgCl_2$ will form red precipitate HgI_2, soluble in excess of either reagent. There are also official: a Mercurous Iodide, Hg_2I_2 and Mercuric Iodide HgI_2.—

The red and yellow Mercuric Oxide are chemically identical; the red oxide is a crystalline substance, the yellow oxide an impalpable powder, and therefore more suited for ointments.

(The yellow subsulphate of Mercury is called "Turpeth Mineral.")

Lead, Plumbum, Pb. Atomic W. 206.4. Val. II.

Preparations and Salts: PbO, Lead Oxide, Litharge. Lead Oxide possesses, of course, basic properties. When this base is used to decompose an oil, it forms an insoluble soap—a Lead Soap, used as "Lead Plaster."

Pb $(C_2H_3O_2)_2$ Lead acetate, (organic acid salt) is commonly called "Sugar of Lead" because of its sweet

taste. It dissolves, when in solution, a certain amount of PbO, forming a solution of basic lead acetate, or "Goulard's Extract." A *diluted* solution of basic lead acetate (lead subacetate) is called "Lead Water."

Arsenic, As. Atomic W. 14.9. Val. III.

Preparations and Salts: As_2O_3. Arsenic Trioxide, "Arsenic," forms with water, and when heated together with a base, or soluble carbonate, an *arsenite,* thus Potassium Arsenite, a solution of which is called "Fowler's Solution," containing 1% of the salt, Potassium Arsenite.

(As_2O_3 is a common ingredient in poisonous preparation for the extermination of mice and rats. The ease with which it is obtainable in this form makes it a frequent cause of suicide and attempts at poisoning. Arsenic may be detected in inorganic mixtures by adding Zinc and HCl, generating Hydrogen, which will combine with arsenic, forming the volatile AsH_3.)

The official chemical antidote is the *Hydrated Ferric Oxide with Magnesia,* prepared by mixing a solution Ferric Sulphate and a solution of Magnesia. The Arsenic combines with the Hydrate of Iron formed, to form an insoluble Arseniate of Iron.)

Antimony, (Stibium) Sb. Atomic W. 119.6. Val. III.

Preparations and Salts: Sb_2O_3, Antimony Oxide.—Antimony Sulphide, Pb_2S_3. Sulphurated Antimony, or "Kerme's Mineral."

A solution of the $SbCl_3$ is called "Butter of Antimony," and is sometimes used as a caustic application.

Bismuth, Bi, Atomic W. 208.9. Val. III.

Preparations and Salts: The common medicinal bismuth salts have one property in common: they are insoluble in water; furthermore, they are basic salts. Thus we have Bismuth subnitrate, $(BiO)NO_3H_2O$ and Bismuth subcarbonate, $(BiO)_2CO_3H_2O$. These basic salts are formed when the neutral salt comes in contact with water.

(A dangerous impurity occasionally found in Bismuth and its salts, is Arsenic.)

Chromium. Cr. Atomic W. 52. Val. II-VI.

Preparations and Salts: CrO_3, commonly called Chromic Acid, is Chromium Trioxide, acid forming. Its salts are the Chromates: Potassium Chromate, and Potassium Bichromate.

Manganese. Mn. Atomic W. 54.8. Val. III.

Of interest only are the salts called permanganates (Potassium permanganate). Mn is an example of a metal which may become an acid-forming element when acting with the highest valence. The permanganates are oxydizing agents, because in acid and alkaline solution they will yield oxygen to other substances.—

MnO_2, Manganese Dioxide, is found in nature as a common source of Manganese. (Solutions of Potassium Permanganate must always be prepared with distilled water, to prevent reduction of the salt by organic matter.)

Iron, (Ferrum.) Fe. Val. II-VI. Atomic W. 55.88.

Iron is one of the best known metals. It is widely distributed in nature, and is a constituent of all animal tissue (Haemoglobin.) It is of some interest to note the different kinds of iron, commercially and technically: *Cast Iron,* containing about 5% of Carbon, and a trace of Manganese and Phosphorus. *Spiegeleisen,* a manganese containing iron. *Wrought Iron,* containing only a trace of Carbon, and must be free from Phosphorus. *Steel* is iron containing about 1% of chemically combined Carbon; it is, according to the method of preparing it, more or less brittle.

Preparations and Salts: Metallic Iron is official as *Reduced Iron,* a pure, powdered form of Iron. The salts may be divided into two classes, the *Ferrous* and *Ferric* Salts, (Val. II and IV respectively.) Ferrous salts easily become oxidized to Ferric salts. Such changes may be prevented through admixtures of sugar to the preparation.

The chief Ferrous Salts are: Ferrous Carbonate, Ferrous Sulphate and Ferrous Iodide. The chief Ferric Salts are: Ferric Chloride (Solution and Tincture), and the Ferric (sub) sulphate (Solution and Powder, "Monsell's.")

Chemical Incompatibility.

When two compounds cannot be mixed in solution without losing their character, and without being decomposed, they are *chemically incompatible.*

Incompatibility exists: a) between compounds forming an insoluble, new compound. b) Between salts and acids, when the acid is stronger than the acid (radical) of the salt, and will replace the weaker acid. c) Between a salt and a stronger base, which will replace the weaker base.

d) Between acids and bases, in general.

(Prescriptions may be written with the view of obtaining the new compounds formed.)

Insoluble Salts: (The oxides, hydrates) carbonates of the earthy and heavy metals; $CaSO_4$, Magnesium Phosphate. Zinc Phosphate, $PbSO_4$, $PbCl_2$, PbI_2, HgI_2, Hg_2Cl_2, AgCl, AgI, AgBr. Iron Salts and Tannic Acid.

b) Inorganic acids liberate organic acids from salts. Any acid liberates Carbonic Acid from its salts. Sulphuric Acid liberates any inorganic acid.

c) KOH, NaOH, $Ca(OH)_2$ liberate NH_4OH.

Oxidizing agents are incompatible with substances which they oxidize.

Chemical Analysis.

A chemical analysis is the process of "taking apart" a mixture or a chemical compound, to determine its composition.

It presupposes definite knowledge of the character of the substance one is trying to detect; the analysis consists in bringing about certain changes that would involve the substance looked for, in a definite manner The first step is always physical inspection and the determination of physical properties of the substance under investigation, such as solubility, odor, taste; one may at times identify substances by these means.

The substance to be analysed may first be tested for organic substances by charring. Having determined, say, that only inorganics are present one may generally proceed as follows:

1. Dissolving the material in water, hot or cold.

II. Remove any insoluble part by filtration, and reserve it for testing.

III. The filtrate may be tested: a) by acidifying a part with HCl, and passing H_2S through it, or b) by passing H_2S through it after making it alkaline with NH_4OH, c) or one may add a soluble carbonate to the solution.

If under III, a-b-c, a precipitate forms, these consist of metallic sulphides or carbonates which are insoluble. The precipitate must then be identified by further testing. (More or less elaborate schemes are found in various text books of Chemical Analysis, to which the student is referred.)

If no precipitate forms, the metals, with the exception of the alkali metals, may be considered absent.

Potassium, in the absence of Na and organic matter may be tested for by the flame test; if K is present, a violet flame.

Sodium colors the flame strongly yellow.

The Determination of Acids.

If the nature of the bases present has been determined, certain acids may be excluded, thus all the acids that would form with the bases insoluble compounds, and vice versa. Certain acids may then be tested for directly, that is, their ions may be precipitated from solutions by reagents that would form insoluble compounds. H_2SO_4 may be precipitated with $BaCl_2$; HCl with $AgNO_3$; KI with $HgCl_2$.

Direct Methods of Testing for Bases.

The preliminary tests having been made as outlined, some bases may be tested for, directly. The principle here again is the formation of insoluble compounds, by bringing together the ions that will form insoluble compounds. Thus *Ca ions* may be removed from solutions by soluble sulphates, or better, by oxalates or carbonates.

Fe ions may be precipitated as the Ferric hydrate or FeS; Ag ions by soluble chlorides as AgCl. Ammonium may be liberated from its salts by KOH or NaOH.

Quantitative Chemical Analysis.

Quantitative Chemical Analysis has for its object the determination of the quantities of the substances under investigation. It may be *gravimetric* or *volumetric.*

Gravimetric Analysis determines the amount present by directly weighing its quantity. An accurate chemical balance is the first requisite. The underlying principles are very simple. *First* the substance must be separated in such a form that it can be weighed. *Second,* the form of the compound must be sufficiently stable to be definite.

An example: The object is to determine the quantity of NaCl present in a solution.

The method consists of removing the Cl in weighable form, from the molecular weight of NaCl we know the amount of NaCl that existed, if the quantity of Cl is known. It is weighed as AgCl. The process is as follows: To the solution is added $AgNO_3$ until a precipitate (of AgCl) no longer forms: $AgNO_3+NaCl=AgCl+NaNO_3$. The precipitate is filtered, washed, and dried. If the weight of the filter paper is accurately known, the filter with contents of AgCl may be weighed; otherwise it is best to burn the filter paper by introducing the precipitate AgCl with filter into a crucible and igniting at a *low* heat, until the paper is consumed, and weighing the residue. Granting that 1.43 grams of AgCl were formed, the moleculer weight of AgCl is (Ag 107.66+Cl 35.37)=143.03. If 143.03 AgCl contain 35.37 grams Cl, 1.43 contain 0.3537 Cl

(= found). Then, the molecular weight of NaCl is (Na 23 + Cl 35.37)=58.37.

35.37 : 58.37 : : 0.3537 : × =0.585 NaCl.

Volumetric Analysis.

This method of quantitative analysis measures by volum the quantity of the substances.

When an acid is thus determined, it is *acidimetry;* when an alkali is so determined is is *alkalimetry.*

The underlying principles of the method are the following, as shown in the volumetric estimation of HCl:

$$NaOH+HCl=NaCl+H_2O.$$

$$40+36.37=58.37+18.$$

That is, one molecule, or 40 parts, of NaOH, will neutralize 1 molecule HCl of 36.37 parts. A solution is therefore prepared containing 40 grams NaOH in 1000 Cubic centimeters. This is called a "Normal" solution.

The whole amount would neutralize then 36.37 grams HCl, or 1 Cubic centimeter 1/1000 of 36.37 HCl, or 0,03637 grams.

The normal solution of NaOH is now added to the solution of HCl until it is neutralized; every cubic centimeter equals 0,03637 HCl. To determine when the neutral point has been reached, an indicator is used, such as litmus, or phenolphthalein.

Note: A normal solution contains the molecular weight in grams to 1000 cubic centimeter; a decinormal solution 1/10 the molecular weight. Moreover, the molecular weight is divided by the acidity of the base, or basisity of the acid, thus H_2SO_4 contains ½ the molecular weight to the liter, it having 2 replaceable H, *dibasic.*

PART III.

ORGANIC CHEMISTRY.

Organic Compounds.

Organic Chemistry is the study of the *Carbon Compounds*—Compounds of Carbon with Hydrogen, including, sometimes, Oxygen, Nitrogen, Sulphur, Phosphorus.

When an inorganic compound is heated with air, ("ignited") it either volatilizes or, (usually), leaves an ash, but it does not char (=become carbonized).

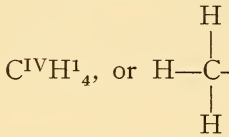
Organic compounds, when ignited, become charred because of the excess of Carbon present ("charcoal"), but when pure, organic compounds are finally completely consumed without leaving ash.

The inorganic compounds were exceedingly simple, —the organic compounds may be very simple or most complex. The classification of organic compounds will be developed in detail in the subject matter. They may be classified in various ways. We shall also meet with acids, bases and salts as in inorganic chemistry.

In all organic compounds C acts with the valence IV, illustrated thus:

Formation of Organic Compounds. Formulae. Open Chain Series.

The simplest organic compound possible would be



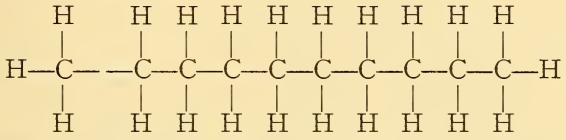
$C^{IV}H^{1}_{4}$, or H—C—H. It is a saturated compound.

All other compounds are *derivatives* from this compound, and, of course, they may only be formed by *substitution* of some other element, or radical, for one or more hydrogens. If one or more H in that compound is taken away, there remains the compound *radical*. CH_4 is a definite compound; so is every new product formed by substitution as stated. These new compounds are called *Derivatives,* as a class.

If the radical CH_3— is linked to a second radical, CH_3, a new compound is, of course, formed, having this formula: $CH_3.CH_3$; the period between the radicals indicates their combination. The formula is a *"Graphic Formula,"* because it describes the formation of the compound.

C_2H_6 is an identical formula as to percentage composition with the preceding. It teaches nothing as to the method of formation, and is called an *empiric formula.*

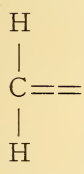
$CH_3.CH_3$ is a compound; $CH_3.CH_2$— would be a radical. Another CH_3— may be linked on, to form the new compound $CH_3.CH_2.CH_3$; a similar linking might be carried on indefinitely. Thus a perfect chain would be formed,



This chain may be *opened* at both ends, to form by substitution, new compounds. The compounds of this series are called "Compounds, or deviatives, of the open chain series."———

Addition Compounds.

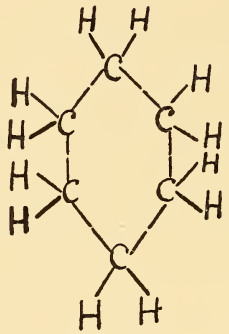
The linking may also take place in this way:



C==C, that is the linking between the radicals may be *double*. Under certain conditions one of the double links may be broken up and taken up by a new element, or radical. In such a case a new compound may be formed by *addition,* and *substitution.*

The Closed Chain Series.

As a basis for this series, six carbons are linked in this way:



C_6H_{12}

This compound so arranged is called a *nucleus,* (from which other compounds may be formed). Every *alternate* carbon may also be linked to its neighbor by a *double* bond, giving then rise to the compound C_6H_6. (Name, Benzene.)

Derivatives: Where the linking takes place by single bonds only, as in C_6H_{12}, substitution derivatives only are possible; with double links, addition compounds, as well as substitution derivatives, are possible.

When, in C_6H_{12}, an H is removed, it leaves the radical C_6H_{11}—; this may be linked to a radical, say CH_3—, to form $C_6H_{11}.CH_3$; now, new compounds may be formed again by further substituting for one or more H remaining in the nucleus, or by substituting an H in the CH_3— radical: The former would be substitution within the nucleus; the latter within the

"side chain" (CH_3—). The compounds would have the same empiric formula, but would be of different chemical character, thus: $C_6H_{10}.OH.CH_3$ (nucleus derivative OH) and $C_6H_{11}.CH_2,OH$ (side chain derivative OH).

The Open Chain and its Derivatives.

The first compound in the chain is CH_4. It is called "Methane." (The series is called also, the "Methane Series.") Its first radical is CH_3—, called *Methyl.* $CH_3.CH_3$ is "Ethane." $CH_3.CH_2$— radical, Ethyl. $CH_3.CH_2.CH_3$ Propane. $CH_3.CH_2.CH_2.CH_3$ is Butane. All these compounds are composed of C and H; *they are called Hydrocarbons.*

Importance of the Hydrocarbons. The Hydrocarbons form the chief constituents of crude petroleum. The smaller the number of *C* atoms in the molecule, the more liquid or volatile they are, and vice versa. Thus CH_4 is a gas, C_6H_{14} a liquid, $C_{20}H_{42}$ a solid. The lighter Hydrocarbons include Benzine, Coal Oil, liquid Petrolatum; the heavier Hydrocarbons, Petrolatum (vaseline), Paraffine. These are of an oily character, or fatty. They do not decompose and become rancid! "Paraffine" is one of the heaviest Hydrocarbons.———

Derivatives of importance: $CHCl_3$, Trichlormethane, or *Chloroform,* and CHI_3, Triiodomethane, or Iodoform. Iodoform liberates nascent Iodine when it is brought in contact with tissue secretions (wounds), and is an antiseptic.

Alcohols, Aldehydes, Acids.

Alcohols are the hydrates of hydrocarbon radicals. Thus $CH_3.OH$, $CH_3.CH_2.OH$, are alcohols. They are derived from the open chain series, by substituting an —OH group for an H. Having in mind the chain, the .OH may be substituted in the first or last CH_3 group in the chain, or in one of the middle CH_2 groups. When in the former it will have the group $CH_2.OH$. When in the CH_2, the group CH.OH. The first would be a *primary* alcohol (characteristic group CH_2OH); the latter a secondary alcohol, (characteristic group CH.OH). Example, Primary Alcohol: $CH_3.CH_2.CH_2.CH_2.OH$. Secondary Alcohol: $CH_3.CH.OH.CH_2.CH_3$.

Products of Primary Alcohols.

When primary alcohol, $CH_3.CH_2OH$, is exposed to the air under certain conditions is loses the H_2 of the primary alcohol group, leaving, in this instance, $CH_3.C.OH$, an *aldehyde,* having the characteristic group .C.OH. The aldehyde then absorbs one O for the two H lost, and becomes an *acid,* $CH_3CO.OH$, the characteristic group CO.OH being called the *Carboxyl* group. Only the H linked in the Carboxyl group is replaceable by a base to form a salt.

"Atomic" Alcohols.

When in a compound of the methane (open chain) series only one .OH radical is introduced we have a *monatomic* alcohol; when two or three .OH are introduced we have a triatomic or diatomic, alcohol.

Alcohols: Methyl Alcohol, $CH_3.OH$ ($HCH_2.OH$). Ethyl Alcohol, $CH_3.CH_2OH$ ($C_2H_5.OH$).

Methyl Alcohol is "wood alcohol," a poisonous product. *Ethyl Alcohol* is "grain alcohol" or the common "alcohol," of which there are the *absolute* (99%), and the "alcohol" of 95% strength. The aldehyde of Methyl Alcohol is Formaldehyde (40% solution is "Formaline"); the acid, formic acid; its salts the formates.

The aldehyde of Ethyl Alcohol is *acetaldehyde,* yielding with Cl, "Chloraldehyde." The acid is *acetic acid,* forming the *acetates* as salts (Potassium, Sodium, Ammonium, Zinc acetates are medicinal.)

Glycerin is a triatomic alcohol, $CH_2OH.CH.OH.CH_2.OH$.

It is a constituent of fats, forming the base, and separated from these by stronger bases (NaOH), which in combination with the acid of the fats form *soaps.* The Sodium Soap is a hard soap; Potassium Soap a soft soap; Calcium Soap and Lead Soap are insoluble soaps.

Uses of Alcohol: Alcohol is a solvent used in pharmacy for the purpose of extracting ground drugs. It is a solvent for resins, volatile oils and castor oil. (*Denatured* alcohol is alcohol rendered unfit for consumption by addition of poisonous substances.) It also gives rise to other compounds.

Glycerin is a solvent for certain substances.

Ethers.

Ethers are the oxides of Hydrocarbon radicals. Thus $(CH_3—)_2O$ forms an ether. Two like hydrocarbon radicals linked to oxygen form *simple* ethers; two unlike hydrocarbon radicals form compound ethers, CH_3———
$CH_3.CH_2$— O

The ether of medicinal importance is "Ethyl ether" $(C_2H_5—)_2O$, the "Ether" of the Pharmacopoeia.

Ether is a very volatile liquid, boiling at body temperature. It is very inflammable. Its vapor is heavier than air. In medicine it is used as an anaesthetic. Ether is prepared from alcohol by the aid of sulphuric acid, which, however, forms no part of the finished product, though it has given rise to the name "Sulphuric Ether." Ether is a solvent for fats and oils.

Esters.

Esters are organic salts. They are formed from an alcohol, as a base, replacing the Hydrogen of an organic or inorganic acids. *The Base* is an alcohol (primary). It has been shown how alcohols may be so changed that they ultimately produce acids. But the primary alcohols themselves are hydrates, and, like the inorganic hydrates, *basic*. Their radical, for example $C_2H_5.—$ or $CH_3.CH_2.—$, can combine with an acid to form a salt. The organic salts can be de-

composed into Base and Acids, by the application of stronger bases, acids, or superheated steam. This process of decomposition is called "saponification," because the type is the process of making soap (*sapo*).

Medicinal Esters of Inorganic Acids.

Ethyl Nitrate, wrongly called nitrous *ether,* is official in the *spirit of nitrous ether.* It acts in the body, chemically, like the inorganic nitrites, but more rapidly. It is more quickly absorbed, being volatile, and is also more quickly eliminated.

Glyceryl Nitrate is commonly called "Nitro Glycerin." It is the active ingredient in the *spirit* of nitroglycerin, or spirit of Glonoin, is rapidly absorbed and eliminated.

Glyceryl nitrate is the chief constituent of Dynamite. It explodes, when struck a blow, with great violence due to its decomposition.

Preparations of Nitrogylcerin must be handled and stored with great care.

Esters of Organic Acids.

These have organic acids and bases. Many of them are found in nature, having the nature of oils. If the base is Glycerin the oil is *fixed;* if the salt is formed by another organic base the oil is *volatile.*

Methyl Salicylate, containing the salicylic acid radical, is in nature found as a volatile oil of Wintergreen. It serves as one source for the production of salicylic acid. The ester is easily saponified.

Ethyl Acetate is commonly called acetic ether. It is not of great medicinal interest.

The Fats and Fixed Oils.

These constitute a large group of organic esters. The base is Glycerin, combined with Oleic, Palmitic or Stearic acid to form the Glycerin Oleate ("Olein"), —Stearate ("Stearin") and—Palmitate. Olein is the chief constituent of the oils; Palmitates and Stearin the chief constituents of solid fats. The process of saponifying these fats and oils constitutes a large industry—soap making. The by-product is always Glycerin. (See "Soaps" under *Glycerin.*) Oils and fats are food products. Fat is stored up in the animal tissue as reserve food material.

Adulteration of fats and oils may be done by the addition of cheaper oils, or of petroleum products. As petroleum cannot be saponified, the degree of saponification that an oil is capable of indicates its purity ("Saponification equivalent").

(Fatty oils and fats may contain other acids than the above, which have been given as types.) The representative oils and fats are: Olive oil, Cottonseed oil, Castor oil, Linseed oil, Lard, Tallow and Butter.

Miscellaneous Organic Compounds (*Open Chain*).

Lactic Acid forms the lactates. Lactic acid is a fermentation product formed in sour milk, hence the name.

Oxalic Acid, (poisonous), forms oxalates.

Tartaric Acid is derived from the crude acid potassium tartrate, a constituent of grapes, and separating from the fermenting juice. The *potassium acid tartarate* is called "Cream Tartar."

Tartaric Acid is a dibasic acid. It forms, sometimes, double salts, like *Potassium and Sodium Tartrate* (Rochelle Salt). *Antimony and Potassium Tartrate* (Tartar Emetic).

Citric Acid. It is an acid found in nature chiefly as the acid constituent of Citrons (Lemons), hence the name. It is a tribasic acid. Its salts are the Citrates. (Potassium, Sodium, and Manganesium citrate). When absorbed the citrates are completely burned (oxidized) in the tissues, to form the carbonates of the base.

Oleic Acid. Oleic acid is the acid radical in Olein, or fatty oils and fats. Its salts are the oleates.

Linoleic Acid is the special acid found in Linseed oil. It differs from Olein chemically, and is the basis of the drying oils.

Amines and Amides.

An Amine is a chemical compound formed by the introduction of an alcohol *radical* (as CH_3.—) into Ammonium by substitution of an H; thus, $CH_3.NH_2$, methylamine.

An Amide is a chemical compound, in which one H, (or more) of NH_3 have been replaced by an acid radical, thus $NH_2.CH_3CO$.

Their chief interest lies in the fact that Amines form as decomposition products of albuminous putrifaction.

Table Reviewing the Classification of Compounds and Derivatives of the Open Chain.

I. *Hydrocarbons.*

II. *Derivatives:* a) $CHCl_3$,CHI_3, (substitution), b) The hydrates of hydrocarbon radicals (alcohols) primary —CH_2OH, and secondary (—CH.OH). c) The oxides of hydrocarbon radicals, ethers.

III. *Oxydation products of primary alcohols:* Aldehydes—, Acids.

IV. *Esters.* (Salts.) Organic bases with organic or inorganic acids.

V. *Amines* and *Amides.*

The Carbohydrates.

These organic compounds were originally so designated because the molecule was found to consist of Carbon with Hydrogen and Oxygen, the latter two elements present in proportion of H_2O, as in water, hence the name, "Carbohydrates."

It has now been determined that they are oxydation products (aldehydes and ketones) of alcohols. The carbohydrates are important food products. The class includes, as typical representatives, Starch and Sugar.

Starch. The formula of starch is $C_6H_{10}O_5$. Starch is an important constituent of many foodstuffs: Potatoes, Rice, Grain. Starch is closely related to *Sugar,* the simplest sugar, Grape Sugar or Glucose, having the formula $C_6H_{12}O_6$, that is, the formula of Starch

plus H_2O. Starch can be made to take up this water molecule and become sugar, by imply boiling it with a dilute mineral acid. This process is called "hydration," or "inversion" of the starch. Ferments (*see*) accomplish the same change.

Cane Sugar has the formula $C_{12}H_{22}O_{11}$. It is the formula of Glucose twice, minus one H_2O. Cane sugar can, like starch, be hydrated or inverted to become Grape Sugar or Glucose $(C_6H_{12}O_6)_2$. Starches or sugar, as food, becomes converted into grape sugar before absorption. (See *Digestion.*)

Cellulose belongs also to the group of Carbohydrates. It is a constituent of vegetable tissue. Chemically, its interest lies in the fact that cellulose can be made to form compounds with the nitric acid radical, the cellulose nitrate, or "Nitrocellulose." It is a highly explosive substance, called "Gun Cotton." Dissolved in ether, cellulose nitrated to a lesser degree and non-explose, forms *Cellodion.* Upon evaporation of the ether a film of the cellulose nitrate is left behind.

II

The Closed Chain Hydrocarbons.

Referring to the illustration of the formation of a closed chain hydrocarbon, we have seen that six *C* atoms are linked together to form the simplest molecule. If the linking between these six C atoms is by a single link, the hydrogen compound of the six C atoms has the formula C_6H_{12}. If every alternate C is united by double links the compound has the formula C_6H_6. This is, in fact, the simplest compound known in practice. We take it as our basis for the derivatives. The derivatives may be obtained *firstly,* by substitution or addition within the molecule (or nucleus) C_6H_6. When the substitution has taken place by a radical, further changes in the new compound may be made by further substitution or addition within the nucleus, or by substitution within the side group (or chain).

The compounds and derivatives of C_6H_6 are also called "the Aromatic Hydrocarbons."

Derivatives by Substitution within the Nucleus.

The compound is C_6H_6, Benzene, or Benzol, (not Benzine). Its simplest radical is C_6H_5—called Benzyl. This may link on to any other radical, organic or inorganic, to form new compounds. For our purpose, the first compound of importance is $C_6H_5.NH_2$. This compound is best called Phenylamine (see *Amines*), because the radical is, for reasons to be stated, also called *Phenyl.* This compound is the basis of the various anilines (dyes) and is commonly called *aniline.*

Acetanilid: When one of the H in the Amine group NH_2 in Aniline ($C_6H_5NH_2$) is replaced by the acetic acid radical, CH_3CO, we obtain the compound "Acetanilid" $C_6H_5.NH.CH_3CO$.

Many other compounds are related to, or are prepared from, aniline; they are the so-called Coal Tar products.

Phenols.

Phenols, as a class, are the *nucleus substitution hydrates* of the closed-chain hydrocarbons. They are *not* alcohols.

$C_6H_5.OH$ is *Phenol* of the Pharmacopoea. It displays, under certain conditions, weak acid properties, though not chemically an acid. It was therefore, called "Carbolic Acid." Carbolic Acid or Phenol is a crystalline solid, soluble in 5, and 95, parts of water, and in any amount in glycerine. It forms weak salts, the carbolates. Phenol is derived, as a rule, from coal tar.

Other compounds belonging to the Phenols:

Crude Carbolic Acid, or Crude Phenol, contains several other related constituents, which are removed by purification. They are, however, valuable as disinfectants, like Phenol itself.

Thymol is a Phenol derived from oil Thyme, chiefly. Its Iodine compound is "Aristol."

Creosote, a product formed by the destructive distillation of wood (Beechwood). "Coal Tar Creosote" is usually contaminated with carbolic acid.

Aromatic Alcohols, Aldehydes and Acids.

Aromatic Alcohols are the hydrates of hydrocarbon radicals of the side groups.

They are formed in this manner:

$C_6H_5.CH_3$; $C_6H_5.CH_2OH$. This is Benzyl Alcohol. The primary aromatic alcohols yield, upon oxidation, the corresponding aldehyde and acid.

Thus, $C_6H_5.CH_2.OH$ is Benzyl Alcohol; $C_6H_5C.OH$, Benzaldehyde; $C_6H_5.COOH$, Benzoic Acid.

Benzaldehyde is a constituent of the volatile oil of bitter almonds. Upon exposure of the oil to the air, Benzoic acid crystals separate.

Benzoic acid is usually made by synthesis, but it may be found naturally in Gum Benzoin, hence its name.

Phenol Alcohols.

It may easily be conceived, how a Phenol and an aromatic alcohol may be formed from the same nucleus, thus: C_6H_6, Benzene; C_6H_5—, nucleus radical Benzyl; $C_6H_5.CH_2OH$, Benzyl alcohol; $C_6H_4.OH.CH_2.OH$, a Phenol alcohol, having the character of a Phenol and of an aromatic alcohol. This Phenol radical does not change the oxydation products of the aromatic alcohol that have been enumerated, but the acids are distinguished as *Phenol* acids. Thus, $C_6H_4.OH.CH_2OH$ yields $C_6H_4.OH.CO.OH$, differing from Benzoic acid in having the additional OH in the nucleus, instead of (the replaced) H; or, it contains

one O more than the Benzoic acid; it is called, therefore, *Oxy*benzoic acid, or specifically, Salicylic acid.

Salts.

Benzoic acid forms Benzoates (of Na., NH_3.)

Salicylic Acid has been prepared from various compounds found in nature. It occurs chiefly in Oil of Wintergreen, as the methyl salicylate, an ester. It is prepared on a large scale synthetically. The salts of salicylic acid are the Salicylates (Na).

To the phenol acids belong also, Gallic and Tannic acid, constituents of many plants. Vegetable preparations, containing Tannic acid, are incompatible with solutions of Iron Salts.

Carbon Compounds of More than One Nucleus.

One or more nuclei of the formula C_6H_6 may link together to form new compounds, giving rise to new derivatives. The chemistry of such compounds is beyond the scope of the present study. Many of these compounds have practical interest from a medical standpoint. Others possess chiefly a technical interest. Those of medicinal interest will be mentioned.

The Derivatives of Vegetable Drugs.

While the study of drugs is part of the study of *materia medica,* some constituents of drugs possess definite chemical interest. Some of them are related to the compounds just considered. Constituents of special interest are

Alkaloids; the word Alkaloid signifies "like an alkali." They are organic, usually crystalline, subtances, the products of vegetable life, which have basic properties; with acids they form salts. Chemically they belong to derivatives of the closed chain hydrocarbons, but contain N in the nucleus.

The free alkaloids are, as a rule, insoluble in water, but soluble in Alcohol, and some in Chloroform and Ether. Their salts are most soluble in water. The alkaloids can be liberated from their salts by stronger bases. There are some insoluble salts of alkaloids, the Tannates, Iodides and Bromides. (Incompatibility!)

Alkaloids are usually the active principles of the drug from which they are obtained. Many are quite potent and toxic. Their English names terminate in *ine;* their Latin names in *ina.* (Example of alkaloids: Morphine, Quinine, Strychnine.)

Cadaveric Alkaloids. When albuminous tissues decompose there are formed certain substances which are extremely poisonous, and have the character of alkaloids. They are called *Ptomaines.* When consumed with decomposed albuminous food, they may cause poisoning. (Example, in cheese, sausage).

Glucosides are constituents, and sometimes the active principles, of plants. As the name indicates, they are related to Glucose. When boiled in aqueous solution with a diluted mineral acid, they will be changed to Glucose and some other substances. Glucosides do not include so many potent substances as the alkaloids. Glucosides are soluble in water. (Example, Digitalin.) The designation of Glucosides has been fixed; their English names terminate in *in;* their Latin names in *inum.*—

Other plant constituents are: The *neutral* or *bitter principles,* the chemistry of which is not well understood. (Example *Aloin*).—

The physical properties of Gum and Resins must be noted: *Gums* are soluble in water; insoluble in alcohol. (Example: Gum Arabic, Acacia.) *Resins* are soluble in alcohol, insoluble in water.

The Extraction of Drugs.

Drugs are extracted in order to obtain pharmaceutical preparations representing the virtue of the drug, in the form of the active constituents, more or less pure; these active principles may be completely isolated (Alkaloids, Glucosides) or be dissolved in the extracting fluid or extract. The extracting fluid is called the *menstruum.* It is required that the drug must be in a proper state of division for purpose of extraction. The menstruum is selected according to the nature of the active constituents to be extracted. An alcoholic, or hydro-alcoholic menstrum is usually chosen, because it has good solvent qualities as well as good keeping

qualities. Among the classes of pharmaceutical preparations are Infusions, Decoctions, Tinctures, Fluid Extracts and Extracts.

Fermentation.

Fermentation is the decomposition of an organic compound through the action of a *ferment*. The ferments are substances that seem to act through mere contact with the substances undergoing fermentation. The ferment does not undergo any changes during the process.

Ferments are classified as *organized* and *unorganized*. The organized ferments are: yeast plants, bacteria or bacilli, and molds; the unorganized ferments are chemical products of cells of the body, or of plants. They further differ in that the organized ferments are inhibited, or killed, by the use of the common antiseptics; the unorganized ferments are not influenced thereby. The unorganized ferments are also called "Enzymes." All ferments are destroyed when subjected to a boiling water temperature.

The chemical changes accomplished by fermentation consist of *hydration* of the substances, or in oxydation (especially within the tissues.)

Putrifaction is the decomposition of albuminous material through anaerobic bacteria.

The *organized* ferments are chiefly represented, a) by the various yeast plants, which bring about alcoholic

fermentation in solution of sugar. (Wine and Beer are common products; likewise Whisky, Brandy, and pure Alcohol.)

b) The *bacteria,* including the "Bacillus Acidi Lactici," producing the lactic acid fermentation; the "bacterium aceti" and other bacteria producing the acetic acid fermentation from alcoholic solutions. The latter oxidize the alcohol to acetic acid, and are found as the "mother of vinegar" in old ciders, etc.—

The *unorganized* ferments include many well known substances. Their names, as ferments, terminate in —*ase,* but this designation is not always employed.

Unorganized Ferments, or Enzymes, are: *Ptyalin,* in the Saliva, *Diastase* in Grain, *Invertin* in Yeast, *Amylopsin* in Pancreatic Secretion changing Starch and Grape Sugar into Glucose. *Pepsin* and *Trypsin,* changing albumins into albumoses and peptones. *Steapsin,* splitting fats, *Enterokinase,* in the intestines changing trypsinogen into trypsin.

The Chemistry of Proteids.

Proteids are organic nitrogenous compounds, containing, usually, the Element C, H, N, O, S and P. The molecule is of exceedingly complex composition. It has never been possible to construct, by artificial means, a molecule of proteid matter.

Proteids make up the contents of animal (and vegetable) tissue cells. A simple representative of proteids

is "Albumen" or Egg-white. Proteid matter is also called albuminous matter.

Physical properties of Proteids: They are soluble in water, or in a solution of Sodium Chloride, but insoluble in alcohol or ether, and they may be precipitated from their solution by certain neutral salts (as Magnesium Sulphate.) They are colloid substances.

By the action of acids and alkalies Proteids may be decomposed; by the action of digestive ferments, they are split up into simpler compounds, thus through the action of Pepsin and Trypsin into Peptones. Their ultimate decomposition products may have a very simple molecular composition, and some are crystalline. An attempt has been made to build up from these ultimate decomposition products, the more complex compounds, with only a limited success so far.

Classification of Proteids.

Proteids may be divided into:

1. *Albuminoids,* including Albumen, Globuline and derivatives, Acid-Albumens, Alkali-Albumens, Albumoses and Peptones.
2. *The Nucleo Albumens.*
3. *Proteids proper:* Glucoproteids and Chromoproteids.
4. *Gelatinoids.*

Albuminoids.

The albumins include Blood—or Serum Albumen, Egg Albumen, and Milk (Lact) Albumen. These albumins are soluble in water, and with acids and alkalies they form the corresponding compounds. The

solution of albumin in water, in the presence of neutral salts, is disturbed by the application of heat—the albumen is "coagulated." They may also be precipitated through certain substances, such as Nitric Acid, Picric Acid, Trichloracetic Acid, and Potassium Ferrocyanide.

Globulins are insoluble in water, but soluble in dilute NaCl solution. They include *Vitellin,* from the Yolk of of Egg, Fibrinogen and Serum Globulin. The remaining members of the group are derivatives of the proteids, as mentioned.

The Nucleoalbumins.

These contain Phosphorous and sometimes Iron. They include *Casein* from Milk.

The Proteids Proper.

The molecule of these compounds consists of part *albuminoid,* and part carbohydrate of other compounds. This is of some importance in the Glucoproteids. One cannot deprive food entirely of Carbohydrates by feeding proteids, for carbohydrates may be derived from certain Proteid compounds.

The Chromoproteids consist of protein with a coloring matter. The most important member of this group is *Haemoglobin,* the iron containing coloring matter of the red blood corpuscles. The coloring matter containing the iron is called *Haematin.* When the combination with oxygen is established, the resulting compound is Oxyhaemoglobin; when the Oxygen has been given off *reduced* haemoglobin is formed. These are the successive changes that go on in the circulation.

The Chemistry of Foods and Digestion.

Foods may be divided into *Starches or Carbohydrates, Proteids and Fats.* These must be associated with inorganic salts and water.

The purpose of taking food is to replace waste products of the body, to supply a source for energy, and to build up tissue. The food is taken, digested, absorbed and assimilated. It may be used up in the body, or remain stored up within the tissue. In general it may be stated that Carbohydrates and Fats supply energy for muscular work. The Proteids replace waste within the cells. The waste, or the resulting decomposition products, are excreted chiefly by means of the kidneys and lungs, also through the skin and gastro intestinal tract.

Digestion.

The purpose of digestion is to so simplify the food molecules that they may be absorbed. The Carbohydrates are digested partly in the mouth, the Proteids in the stomach, and the Fats within the intestines through the intestinal and pancreatic secretions. In some animals the digestive organs are differently arranged, but the chemical process is the same.

Carbohydrates.

Carbohydrates are inverted within the mouth, through the action of the *Ptyalin* (ferment) in the saliva, to sugar. If the inversion is not completed through the saliva, it is completed through the ferment *Amylopsin* from the pancreas, when the food reaches

the intestines. The fluids in which Ptyalin and Amylopsin act, must be alkaline. All Carbohydrates are absorbed as Grape Sugar. (*See* Chemistry of Carbohydrates.)

Proteids.

They are digested within the stomach. The stomach secretes a ferment called *Pepsinogen;* it is a type of a *pro*-enzyme, to form the enzyme proper. The stomach also secretes a fluid acid with HCl. This acid changes the pro-enzyme pepsinogen to pepsin.

The proteid food is first changed by the acid to acid-albumen; after this the pepsin digests the albuminous food to albumoses, and ultimately to peptones.

The digestion of all food is not completed within the stomach. The partly digested food is propelled into the intestines where the process is completed.

Intestinal Digestion.

In man and in some animals the intestines form the chief organs of digestion. The digesting fluids within the intestines are the juices of the intestines ("succus entericus"), the secretion of the pancreas, containing Trypsin, Amylopsin, and Steapsin, assisted by the bile.

The Carbohydrates are finally inverted to Grape Sugar through the Amylopsin; the Proteids through Trypsin to Peptones, and the Fats, being first ennulsified through the alkaline solutions within the intestines are, perhaps, partly decomposed through the Steapsin.

After the digested food has been absorbed, the undigested and indigestible food passes through the intestinal canal and is excreted. It has lately been claimed,

that the cellulose which constitutes a great part of the foods of many animals, is decomposed within the intestines through a ferment residing within the cellulose.

Assimilation and Excretion.

The Carbohydrates, or Sugar, absorbed are stored up (and used), as *Glycogen* within the liver. So much of the nitrogenous food as is needed to replace waste becomes a constituent of the tissue cells. The Fats are either "burned" or stored up as fat within the tissues. (It is possible that fat may also be formed from the other foods.)

A body may increase in weight, *first,* by an increase in the amount of tissue; *second,* by an accumulation of fat within the tissue.

The *inorganic salts* of food consist chiefly of *Sodium Chloride,* of the *phosphates,* and *sulphates.* They are needed to hold the proteid matter in solution within the blood, and to supply some of the constituents of the secretions. The water is needed to dissolve the digested food, and to dissolve, for purpose of elimination, the waste products of the tissues. It is needed to maintain the balance of fluids in the tissue to replace the excreted water.

All changes involved in the process of metabolism are carried on by ferments within the tissue cells.

Decomposition Products.

Through the burning of Carbohydrates in the tissues there are produced CO_2 and H_2O, the former excreted through the lung. The fats give rise to similar decomposition products.

The decomposition of the Proteids within the tissue gives rise to many products, which go through a great many changes within the tissues, chiefly within the liver, until they are finally excreted as *Urea,* or *Uric Acid.* Urea is the chief product of Proteid decomposition in man. In some animals (birds) Uric Acid seems to take its place. Some of the intermediate products between Proteid and Urea are the Xanthin bases.

These decomposition products, dissolved in water, are excreted in the *Urine.*

The Chemistry of the Urine.

The Urine consists of:

a) *the solids* in solution: *Urea* and *Uric Acid* and other nitrogenous decomposition products; the *inorganic salts:* the phosphates, chlorides and sulphates of Potassium, Sodium, Calcium, Magnesium and Ammonium.

b) the water holding these substances in solution.

The percentage composition of the Urine varies with the Urine of different animals, and with other circumstances. Thus a large amount of water consumed and excreted dilutes the Urine.—The nitrogenous constituents are the decomposition products of cell metabolism, and of food consumed.

The inorganic constituents are partly derived from nitrogenous matter, (sulphates and phosphates), but mostly from the mineral constituents of food.

The Urine Under Pathological Conditions.

Under pathological conditions, the Urine may differ from the normal:

1) The Urine as a whole may be suppressed.

2) There may be want of excretion of the solid constituents of the Urine.

3) There may be abnormal constituents of the Urine, such as albumen, sugar, pus, blood, and indican.

4) There may be an increase in the quantity of certain solid constituents of the Urine, denoting greater waste.

The Clinical Examination of Urine.

The object of the Clinical Examination of the Urine is to detect certain changes from the normal as an aid to diagnosis.

In veterinary medicine the practical application of the urine analysis is still quite undeveloped, but, like in medicine in general, it will, doubtless, become of greater importance. The clinical methods of examination are, therefore, described.

1) *Physical Examination.* The quantity of 24 hours is measured. The Urine is inspected as to color, odor, and the presence or absence of sediment. The specific gravity is taken and compared with the normal: Increase of solids increases sp. gr., and dilution decreases it.

2) The specimen is then filtered.

3) *Chemical Examination:*

Reaction with litmus paper, acid or alkaline. The reaction of the Urine may depend largely upon the

character of the food; an acid or alkaline reaction may, therefore, be normal.

The total solids may be estimated from the specific gravity; or they may be determined by evaporating 10 grams of the Urine to dryness upon the water bath.

The Calcium salts may be determined by igniting the residue after evaporation, extracting with diluted HCl, neutralizing the excess of HCl, and precipitating the Calcium with Ammonium Oxalate, drying and weighing the residue. (It has been suggested, that in *Osteoporosis* there is an absorbtion and excessive elimination of the Calcium from the bone tissue, and that the analysis of the Urine may lead to an early differential diagnosis.

Albumen may be most readily detected by coagulating the same by boiling, or by the addition of nitric or acetic acid.

The albumen may also be precipitated by the addition of picric acid, trichloracetic acid, or potassium ferrocyanide.

Sugar may be detected by boiling the specimen with *Fehling's Solution* (alkaline cupric tartrate solution.) If sugar is present, a precipitate of reduced Copper Oxide is formed.

Indican. It is believed that indican in the Urine is a sign of excessive albuminous putrifaction in the intestines. On the other hand a varying amount may be found as a normal constituent of Urine. It may be detected by heating the Urine with an acid (HCl) containing an oxidizing agent (Ferric Chloride): a blue color indicates the presence of Indican.

Pus in Urine is detected by the microscope.

Blood Cells may likewise be detected with the microscope.

Blood Coloring Matter may be detected chemically by adding to the Urine H_2O_2, and a freshly prepared tincture of guaiac: a blue color indicates haematin. Under the same circumstances a tincture of aloin gives a cherry-red color.

The Chemistry of Milk.

The *Character of Milk.* Milk is a fluid composed of water and substances suspended or dissolved therein. Pure milk may be white or yellow-white in color, and possesses a more or less "rich" taste, faintly sweet. Upon standing, milk will separate into an upper layer ("Cream") and a lower layer.

Whole milk contains from 12—16 per cent of solid matter, "total solids;" the balance is water. The "total solids" are composed of from 3—5 per cent of fat; the balance is *casein,* the proteid of milk, with a smaller amount of milk-sugar, and inorganic salts.

The fat is sometimes called "butterfat;" it is composed of glycerine with various fatty acids, and is suspended in fine globules surrounded by the albuminous constituents of the milk. Some herds of cows produce a milk very rich in fat (Jerseys); other herds produce less fat (Holsteins). A milk may be rich in fat and not possess the "rich" yellow-white color.

Cream consists of the butterfat of the milk plus casein. It rises to the surface upon standing, or may be separated through centrifugal force. The former is called gravity cream, and contains usually about 23 to 25 per cent of fat, depending upon the character of the milk. The centrifugal cream may contain from 8—46 per cent of fat.

Butter is formed when, by means of churning, the fat is entirely liberated from the enclosing proteid matter.

Skimmed Milk is the milk deprived of its cream. It still contains some nutritious material of lact albumen,

milk-sugar, a small amount of residuary fat and casein. It is more or less bluish in color and transparent or translucent.

Casein is held in solution in the milk through its combination with calcium phosphate. When this compound in the milk is broken up by the addition of an acid, the casein precipitates as curds. It may likewise be precipitated through the milk curdling ferment *rennin,* but this precipitate is not deprived of its calcium salts.

The Fat and Casein, with the milk-sugar, constitute the chief nutritive substances of the milk.

Milk forms one of the most important food products. It is especially desirable and necessary that the milk be pure.

The Bacterial Contents of Milk.

Milk is a sterile fluid, but there are so many sources of contamination that it is never produced as a sterile fluid. A very good grade of milk will contain some 10,000 bacteria to the cubic centimeter; the worst milk on the market may contain 5,000,000 bacteria to the cubic centimeter. These bacteria may or may not be pathogenic. (They may include the bacilli of tuberculosis from tuberculous cattle.)

The bacterial contents of milk may be killed to some extent by heating the milk, that is *Pasteurizing* or *Sterilizing* the milk. But the milk loses it value as a food to some extent through this process. At any rate, the effort must be to *produce pure milk,* and not to hide the dirt in milk.

The Production of Pure Milk.

Pure milk is milk sufficiently rich in constituents (solids) to meet the requirements provided, and sufficiently clean that its bacterial contents does not exceed the established limits. Different states and communities have fixed different standards of fat contents, and total solids. The average is perhaps 12.00 per cent total solids, and 3% of fat. The regulation of the bacterial contents has not been so thoroughly established.

Requirements for the Production of Pure Milk.

The Cows of the herd must be free from constitutional and local disease (Tuberculosis!) All cattle should be tested by the tuberculin method for tuberculosis, and infected cattle at once excluded.

The Food for the Cows must be suitable and sufficient; the feeding of "wet slop" from breweries, containing fermentation products, must be excluded. The dried residue of brewery slop may be permitted. All cattle must be allowed sufficient exercise in the open air, and sufficient pasture in season.

Milk-producing cows should be stabled under conditions of absolute cleanliness. The nearer conditions of milking approach surgical cleanliness, the less danger there will be of contamination of the milk.

The milk should be promptly cooled, and delivered with a temperature not exceeding 50° F.

Adulterants in Milk.

The adulterants may be: a) *Water,* to dilute the milk; b) the cream may be removed by *skimming.*

Milk so treated is "thin," sometimes bluish; c) *Coloring matter* may be added to give whole milk a desired "rich" yellowish color, or to cover evidence of diluting or skimming; d) *Preservatives* may be added such as *Formaldehyde* or *Boric Acid.*

Examination of Milk.

In order to establish the character of milk it must be examined bacteriologically and chemically. The bacteriological examination is made by making cultures of the milk upon plates, and counting the colonies.

The Chemical Examination:

a) Physical Inspection: The presence or absence of a sediment is noted; the color and odor of the milk, and its taste; the separation of cream.

To separate sediment: Dilute the milk with water; close the neck of percolator with a cork; fill the percolator with milk, allow the sediment to seperate in the neck. Draw off (siphon) the clear supernatant milk; dilute the balance with water, allow to stand, and repeat dilutions until all sediment has separated. The sediment may then be further examined.

b) *Chemical Analysis:*

The specific gravity of the milk is depending upon the fat and upon the "solids not fat" in the milk. It alone is not an absolute indication of the value of the milk.

The acidity in milk is caused by carbonic acid and acid phosphates of the milk, when quite fresh. In older milk the acidity is increased by fermentation lactic acid.

In fresh milk of the best quality the total acidity does not exceed 0.2% as lactic acid.

The chief reliance in chemical analysis must be placed upon the estimation of total solids, and fats.

Total solids are estimated by drying 5 grams of milk upon the water bath to constant weight. The difference in weight is the water; the residue the "total solids."

The fats are estimated by separating them from the milk as follows: 20 grams of milk are mixed with 20 grams of pure (U.S.P.) HCl in a flask, and heated upon a water bath until a chocolate-brown color is produced—i. e. until the organic matter is destroyed. The contents are cooled, and 20 grams of ether are added to the flask, agitated during 10 minutes, the ether allowed to separate, and poured off into a clean weighed flask. The ether extraction is repeated 2 or 3 times with 10c.c. of ether; the ether extracts are mixed, the ether evaporated or distilled off, the residue dried at water bath temperature, and weighed, and calculated to 100 grams.

The *"Solids not Fat,"* are the total solids minus the fat.—

Formaldehyde is detected by boiling 1 part of milk with 4 parts of pure HCl, containing a trace of Ferric Chloride; a violet color indicates Formaldehyde.

Boric Acid is detected by taking 1 drop of the milk, 2 drops of HCl, and 2 drops of Tumeric Tincture, mixing them in an evaporating dish, and drying upon a water bath, and add to the residue one drop of Ammonia Water. Boric Acid or Borax produces a bluish green color.

Coloring Matter may be readily detected by precipitating the casein in milk with rennin. If artificial coloring matter has been added the curds of casein will be colored.

Modified Preparation of Milk.

Condensed Milk is whole milk evaporated in a vacuum; the residue may or may not contain added sugar as a preservative.

Modified Milk is milk in which the relative proportions of cream and proteids have been altered by the separation, or addition of cream. It meets to some extent the demands of infant feeding.

The Chemical Analysis of Meat and Food Products.

Meat and food products may be analyzed for the purpose of determining their constituents of food value, or of detecting adulteration.

Food products may be adulterated for the purpose of preservation, or to increase bulk, or for other reasons.

The methods of analysis depend upon the physical character of the material, upon its chemical composition, and upon the substance tested for. Certain general rules may be laid down as applying to the analysis of food stuffs in general.

The detection of foreign constituents in foods generally necessitates their isolation in sufficiently pure form to be identified by certain tests.

Taking meats or other solid food as the type, the different steps are as follows:

1. Comminution of the material, by cutting or grinding.

2. Separation of adulterants by:
   a) Extracting with a suitable solvent, or
   b) Charring and extracting the residue, or
   c) Igniting and extracting the ash.

2 a) *Extracting with Suitable Solvents.* A convenient quantity, say 50 grams, may be taken. Put into a flask, dish or beaker, the solvent is poured upon it, and it is allowed to macerate or digest for a sufficient length of time. It is then filtered, and the filtrate investigated.

The Choice of Solvent depends: a) Upon the nature of the substance to be extracted, and b) Upon the nature of the material under investigation.

a) It is required to be a good solvent for the substance to be extracted; thus one may choose *water* (hot or cold) acid or alkaline; *Alcohol, Ether.*

b) Such a solvent should be selected, where there is a choice, that will dissolve least of other undesirable substances from the material.

The filtrate may be tested, if sufficiently pure, for certain constituents directly, or these may be separated by chemical and physical means; thus, an immiscible liquid may be shaken with the solution that certain substances, if present, may pass into this second liquid. (See *Salicylic Acid.*)

2 b) *Charring and Extracting the Residue.* "Charring" is the carbonizing of the material by burning it to blackness. Its *purpose* is to destroy certain interfering constituents of the material, so that the adulterant may be more easily extracted. It is *not applicable* where the suspected adulterant would also be destroyed by heat (organic substances), but only applicable where inorganic and nonvolatile substances are tested for.

2 c) *Igniting and Extracting the Ash.* The object of the process of ignition is to destroy all organic matter, and examine the ash. It is only applicable to inorganic nonvolatile substances.

Special Method: When volatile substances are present, such as sulphurous acid, they may be directly separated by subjecting the Extractive from 2 a) to simple distillation.

The Analysis of Fluid Foods.

Fluid foods may be subjected to direct distillation for volatile adulterants, or shaken out with an immiscible solvent (as for salicylic acid), or they may be treated as solid foods, and charred or ignited.

It must be clearly understood that the above are general methods. The character of the food and of the adulterant may be such that the ordinary methods are not applicable, and all the resources of the analyst may be taxed for the devising of suitable processes, but for these, special works must be consulted, such as *Leach, on Food Analysis,* or others. They are usually only acquired through long laboratory experience.

Special Processes.*

The Examination of Meats for the More Common Adulterants.

Salicylic Acid, Boric Acid, and Sulphurous Acid are, perhaps, the most frequently employed preservatives in meat; the direct methods employed for the detection of these adulterants are as follows:

For Salicylic Acid. The meat is extracted directly with ether; the ether is poured off (*decanted*), evaporated, a few drops of hot water added to the residue, and a drop of the solution of Ferric Chloride added; if salicylic acid is present, a violet color is produced.

Note: The fatty parts of the sample interfere by dissolving in the ether, and these must be removed by

*(*Leach,* Food Inspection and Analysis, has been extensively consulted.)

mechanical means prior to extraction. If *Salicylates* are present, the watery extractive must be made acid by a few drops of sulphuric or hydrochloric acid, and then shaken out with ether.

Boric Acid, either free or as borates, is detected by adding sufficient water to the meat to rub it into a thin pasty mass; this soluiton is made acid by HCl, and digested for ½ hour. Filter paper saturated with Turmeric Tincture is then dipped into the solution; a red coloration of the paper, turned a blue-gray by ammonia, denotes boric acid.

Sulphurous Acid may be present, free or as *Calcium Bisulphite.* It is not infrequently found in minced meat.

Detection: Take 25 grams of meat, mix well with 100. CC of water, and acidify with phosphoric acid. Distil this mixture and treat the distillate with bromine water, or bromine, to oxidize the sulphurous acid to sulphuric acid, and add a solution of $BaCl_2$; a precipitate of $BaSO_4$ denotes the presence of sulphides in the sample.

Note: The odor of the sample may suggest the presence of H_2SO_3.

Saltpetre, or KNO_3, is frequently employed in meat preparations to preserve the natural color. It may be detected by adding to the finely divided material a 1% solution of diphenylamine in H_2SO_4; nitrates produce a blue color.

Starch-containing Material may be detected by extracting the material with water, and adding a drop of Solution of Iodine (Lugol's Solution); a blue color denotes Iodine.

Glycogen is a constituent chiefly of horse flesh. It may be detected by extracting the material with water, and adding a few drops of Lugol's Solution of Iodine; a wine color indicates Glycogen. It disappears upon heating, and appears again upon cooling.

The Analysis of Fats and Oils (Edible.)

Butter.

For the present purpose, any butter other than the fresh butter, uncontaminated, is called adulterated.

Adulterated butter may consist of "Renovated Butter," or admixture with oleomargerine; or it may contain coloring matter, or preservatives.

Renovated Butter is butter which has become rancid, and which has been so treated as to remove the evidence of rancidity by "aeration" and other processes.

Detection: The simplest test is the *foam test* (cited in *Leach,* Food Analysis); a teaspoonful of the butter is melted in a spoon under constant stirring, over a low bunsen flame; fresh butter boils quietly with the production of a rich foam. *Renovated* butter (and oleomargerine, also), boils with much sputtering, without foam. *Oleomargerine* may be detected by the above test. The odor of the hot, melted butter is characteristic; the oleomargerine odor suggests meat. The taste, especially to those experienced, offers a valuable guide.

Detection of Coloring Matter (Martin.) About 5 grams of butter are extracted with Carbon Bisulphide containing 15% of Methyl or Ethyl Alcohol. The solution separates into two layers, the lower containing the fat dissolved in the CS_2, and the upper layer containing

the alcohol with the coloring matter, if present in solution.

This alcoholic layer may then be tested: Ammonia added burns the fluid brown: *Turmeric.*

$AgNO_3$ produces a black color: *Marigold.*

If the evaporated alcohol solution leaves a residue turning blue with H_2SO_4, *Annato.*

Detection of Aniline Colors or Annatto (Doolittle.) Dissolve in two test tubes a small quantity of the butter (or fat), in ether. Add to one test tube 2c.c. HCl, to the other test tube 2c.c. KOH Solution. The aniline dye colors the acid tube red; the annatto the KOH tube, after standing some time.

Detection of Formaldehyde: Add the melted butter to milk, and test the milk for formaldehyde. (See *Milk Analysis.*)

Detection of Salicylic Acid:

Extract about 25 grams of butter with Sodium Bicarbonate in water; this will form Sodium Salicylate; liberate the acid by H_2SO_4, and extract with ether; test the residue upon evaporation with Solution of Ferric Chloride: Violet color denotes Salicylic Acid.

Edible Oils.

The edible oils include Olive Oil, Cottonseed Oil, Sesame Oil, Rape Oil, and Peanut Oil. Adulteration of these oils consists chiefly of the addition of cheaper oils to the more expensive oils, thus Olive Oil may be adulterated with Cottonseed Oil. The analysis is not always easy especially the quantitative estimation of adulterants. For the latter purpose the "saponification equiv-

alents" and "Iodine" and "Bromine" values are of especial value. For qualitative testing certain tests may be relied upon. The test for Cottonseed Oil will suffice for the present purpose. It is called:

Halphen's Test. The reagent consists of equal parts of Amyl Alcohol and Carbon Bisulphide, containing 1% of Sulphur in solution. Equal volumes of the fat and this reagent are mixed in a loosely-stoppered test tube, and the mixture is heated for 15 minutes in a bath of boiling brine: a red color denotes the presence of Cottonseed Oil.

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